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Measurements of Indoor Pollutant Emissions from EPA Phase II Wood Stoves

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ABSTRACT

Measurements of indoor pollutant emissions were made on four wood stoves meeting the EPA Phase II emission requirements in a 37 m^2 (400 ft^2) test house at NIST. The stoves were operated in a manner consistent with typical residential use and in accordance with the manufacturers' instructions. Three tests were conducted for each stove, with each test lasting approximately ten hours. During the tests the following quantities were monitored: combined gaseous and particulate phase concentrations of 13 individual polycyclic aromatic hydrocarbons (PAHs) averaged over the test period, including benzo[a]pyrene (B[a]P); total particulate phase PAH concentrations using a real-time monitor; mass of particulate matter below ten μm in diameter (PM10) averaged over the test period; continuous particle counts in six size ranges; continuous indoor and outdoor concentrations of carbon monoxide and carbon dioxide; building air change rates; pressures across the test house walls and in the stove flue; wind speed and direction; and indoor and outdoor air temperature and relative humidity. Based on these measurements, emission rates of total PAHs (i.e., the sum of eight individual compounds) ranged from 0.05 to 0.24 ng/s and total PAH source strengths ranged from 67 to 711 ng/kg of wood. Emission rates of B[a]P ranged from 0.003 to 0.028 ng/s and B[a]P source strengths ranged from 7 to 90 ng/kg of wood burned.

Keywords: benzo[a]pyrene, emission rates, indoor air quality, particulates, polycyclic aromatic hydrocarbons, wood stoves

DISCLAIMER STATEMENT

Certain commercial equipment are identified in this report to describe the instrumentation used in the tests. The mention of trademarks or registered trade names of commercial products in this report does not constitute endorsement or recommendation for use by the National Institute of Standards and Technology, nor does it imply that the equipment identified are the only appropriate or best available devices for the purposes cited in this report.

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TABLE OF CONTENTS

ABSTRACT iii

INTRODUCTION 1

DESCRIPTION OF TEST HOUSE AND STOVES 1

MEASUREMENT PROCEDURES AND INSTRUMENTATION 3
- Measurement Techniques and Instrumentation 3
  - Average PAH on Sorbent Tubes 3
  - Real-Time PAH and Building Pressures 5
  - PM10 6
  - Particle Counts 7
  - Carbon Monoxide, Carbon Dioxide and Relative Humidity 7
  - Building Air Change Rate, Temperature and Wind Speed 8
  - Wood Consumption 8
- Test Protocols 9
  - Stove Operation 9
  - Instrumentation 10

RESULTS AND ANALYSIS 11
- Summary of Tests 11
- Test Results 12
- PAH Measurements with Sorbent Tubes 14
  - PAH Concentrations 14
  - PAH Emission Rates 18
- Carbon Monoxide Emission Rates 24

SUMMARY AND DISCUSSION 25

REFERENCES 26

ACKNOWLEDGEMENTS 27

FIGURES 29

APPENDIX A STOVE OPERATION PROTOCOL 35

APPENDIX B INSTRUMENTATION PROTOCOL 37

APPENDIX C TEST SUMMARY TABLES 41

APPENDIX D PAH CONCENTRATION RESULTS 57

INTRODUCTION

In 1990, the U.S. Consumer Product Safety Commission (CPSC) staff completed a preliminary assessment of the risk of cancer from benzo[a]pyrene (B[a]P) and other polycyclic aromatic hydrocarbons (PAHs) associated with indoor wood stove emissions. While the CPSC risk assessment was in progress, the U.S. Environmental Protection Agency (EPA) set requirements to reduce particulate emissions into the outdoor air from wood stoves. The final requirements are referred to as the EPA Phase II requirements. Because of the changes in wood stove design made to comply with the Phase II requirements, CPSC is updating their cancer risk assessment. Current indoor PAH emission rate data are required by CPSC in order to perform this risk assessment. This report presents the results of indoor PAH emission rate measurements performed on four wood stoves complying with the EPA Phase II requirements.

There have been several studies of the impact of wood stove operation on the indoor concentrations of PAHs and other contaminants (Offermann 1994; Knight et al. 1986; Knight and Humphreys 1985; Traynor et al. 1987). Based on the stove designs at the time, these studies concentrated on the difference between airtight, non-airtight and catalytic stoves. Some of these studies were designed to assess human exposure to indoor PAHs from a variety of sources, including the outdoor air, fireplaces, wood stoves, cigarette smoke and combustion appliances (Offermann 1994; Sheldon et al. 1993a). The study presented in this report is concerned only with indoor emissions from wood stoves meeting the Phase II requirements. The primary objective of this study is to determine the PAH emission rates from these stoves with specific emphasis on B[a]P emissions.

In order to assess PAH emission rates and source strengths from the wood stoves tested in this study, the stoves were installed in a small test house and operated in a manner consistent with typical residential use and manufacturers' instructions. Each test consisted of about ten hours of stove operation, during which a variety of parameters were measured including indoor PAH concentrations and building air change rates. Based on the data collected, a single-zone mass balance analysis was used to determine PAH emission rates in units of nanograms emitted per second and source strengths in nanograms emitted per kilogram of wood burned. These emission rates and source strengths were determined for the sum of eight PAH compounds and for B[a]P. The PAH concentrations, emission rates and source strengths were determined for the gaseous and particulate phases combined.

DESCRIPTION OF TEST HOUSE AND STOVES

The tests were performed in a single-room test house located on the NIST campus (Burch et al. 1982). The test house has a floor area of 37 m^2 (400 ft^2) and contains no interior partitions. The one-story structure has a ceiling height of 2.3 m (7.5 ft) and an interior volume of 85 m^3 (3000 ft^3). It has uninsulated wood frame walls, an exterior facade of paneled wood, and an interior finish of painted gypsum board. The foundation is slab on grade, with an unpainted concrete floor. The house has an uninsulated, ventilated attic and an asphalt-shingled, pitched roof. There are two double-hung windows with storm windows on the north and south walls and a metal exterior door filled with perlite insulation at the north end of the east wall. The house has a 4.1 kW (14,000 Btu/h) electric-resistance, forced-air heating unit and a 3.8 kW

(13,000 Btu/h) air conditioner. A schematic elevation of the test house is shown in Figure 1, showing the dimensions of the structure and the stove installation.

The airtightness of the house was determined with a fan pressurization test conducted according to ASTM Standard E779-87 (1992). Based on this test, the building air change rate at 50 Pa is 6.5 air changes per hour (ach), and the effective leakage area at 4 Pa is 130 cm^2 (20 in^2). Based on the single-zone infiltration model in the ASHRAE Fundamentals Handbook (ASHRAE 1993), these results correspond to an air infiltration rate of 0.3 ach under typical winter conditions. As discussed later in this report, the air infiltration rates of the test house were monitored during the stove tests using the tracer gas decay technique.

Four wood stoves were tested in this study. Two were made of cast iron, and the other two of welded steel. One of each pair had a catalytic converter. Based on the small size of the test house, stoves with the minimum heat output rating in each of the four categories were selected for the tests. In this report, the four stoves are referred to as A, B, C and D as follows:

A Cast iron, catalytic: 3.2 - 9.0 kW (10,900 - 30,600 Btu/h),
B Cast iron, non-catalytic: 2.6 - 6.6 kW (8,700 - 22,500 Btu/h),
C Welded steel, non-catalytic: 3.1 - 13.0 kW (10,500 - 44,500 Btu/h),
D Welded steel, catalytic: 3.0 - 7.9 kW (10,100 - 26,900 Btu/h).

The stove manufacturers provide a heating capacity for each stove in terms of the floor area that it can heat. These ratings are approximate in that they do not account for climate or the thermal characteristics of the house being heated. Stoves A and B are rated to heat up to 110 m^2 (1200 ft^2), Stove C is rated to heat 90 m^2 (1000 ft^2), and Stove D is rated at 200 m^2 (2200 ft^2). Stoves A, B and C rely on radiant heating, while Stove D has a fan to heat the room through convection.

The smoke emission ratings of Stoves A, B, C and D were 3.6, 2.9, 6.1 and 3.4 g/h respectively. Their average efficiency ratings were 72%, 63%, 63% and 72%. Stove A had a sliding draft control, to control the flow of room air into the stove, and a damper bypass control, to allow the flue gases to bypass the catalytic converter. Stove B had a sliding combustion air inlet control and a spin draft control, both used to control the flow of room air into the stove. Stove C had only a single combustion air intake control, making it more difficult to control the stove temperature. Stove D had two sliding combustion air inlet controls and a catalytic converter bypass control.

Before testing, each stove went through a break-in process wherein five progressively larger fires were burned to cure the high-temperature stove paint. A stove thermometer was attached 10 cm (4 in) up the flue pipe from the stove top to monitor the stove temperature during the break-in process and during the subsequent testing. The first break-in fire lasted one hour at a stove temperature of 200 °C (400 °F). The following four fires were made progressively hotter, the last of which burned at a stove temperature above 400 °C (750 °F) for at least one hour. The stoves were allowed to cool to room temperature between each fire. The wood used in the tests was oak that had been seasoned for approximately one year.

MEASUREMENT PROCEDURES AND INSTRUMENTATION

This section describes the measurement procedures and instrumentation used in the wood stove tests. The measurement techniques and instrumentation are presented first, followed by a discussion of the test protocols.

Measurement Techniques and Instrumentation

This section describes the measurement techniques and instrumentation used in the wood stove tests. As mentioned earlier, the following quantities were monitored during the tests: combined gaseous and particulate phase concentrations of individual PAHs averaged over the test period, including benzo[a]pyrene (B[a]P); total particulate phase PAH concentrations using a real-time monitor; mass of particulate matter below 10 μm in diameter (PM10) averaged over the test period; continuous particle counts in six size ranges; indoor and outdoor concentrations of carbon monoxide and carbon dioxide; building air change rates; pressure differences across the walls of the test house and pressure in the stove flue; wind speed and direction; and indoor and outdoor air temperature and relative humidity. Figure 2 is a schematic floor plan of the test house, showing the instrumentation systems and the sampling locations.

Average PAH on Sorbent Tubes

Average PAH concentrations were measured by sampling air using a sorbent tube with a quartz filter and analyzing an extract from the sorbent and filter with liquid chromatography (LC) and fluorescence spectrometry (FS). Although the tubes contained both XAD-2 sorbent and a quartz filter, they are referred to simply as sorbent tubes in this report. Six air samples were collected during each test, three during a long sampling period and three during a short sampling period. The long period began just before the fire was started in the wood stove, and the short period began after the second loading of wood into the stove. Both sampling periods ended at the same time, roughly 10 h after the fire was started. Therefore, the long sample was collected over about 10 h and the short sample over about 8 h. Two short samples and two long samples were collected indoors, about 1.5 m (5 ft) above the floor at the locations shown in Figure 2. For each test, a short and a long sample were also collected outdoors at a distance of about 36 m (120 ft) from the test house.

The sorbent tubes were manufactured by Supelco (Bellefonte, PA), and are shown schematically in Figure 3. The glass tubes had an overall length of 12.5 cm (5 in), a 2.54-cm (1-in) outside diameter (OD) at the inlet and a 0.95-cm (3/8-in) OD at the suction end. The tubes were packed with two 2.5-g beds of XAD-2 sorbent material separated by a polyurethane foam (PUF) plug. PUF was also placed at each end of the tube to retain the XAD-2 sorbent during handling and sampling. A quartz fiber filter was placed outside the PUF plug at the air inlet end of the tube to retain particulate phase PAHs. The sorbent tubes were received from the manufacturer wrapped in aluminum foil and inside screw-capped, colorless glass jars. The tubes were pre-cleaned by the manufacturer using EPA Method 0010. This method consists of four 22-h periods of Soxhlet extraction using water, methyl alcohol, and then methylene chloride twice. In addition, prior to sampling, NIST pre-cleaned the tubes in Soxhlet extractors for 24 h using methylene chloride. The tubes were then wrapped in clean aluminum foil, replaced in the glass jars and stored in a freezer at -23 °C (-9.4 °F).

Air samples were collected on the sorbent tubes using Gilian AirCon-2 air sample systems (Caldwell, NJ). These systems consist of a high-volume, positive-displacement sample pump, a telescopic mast and a sample hose. The pump is capable of maintaining constant flow over a range of 2-20 L/min (liters per minute), and the sample hose has a support tip to mount the sample at the top of the mast, which can be extended up to 1.5 m (5 ft). The airflow is set with an external flow knob, and the nominal flow rate is indicated on a built-in rotameter. Most of the test samples were collected with the pumps operating at 10 L/min. However, airflow rates of 15 and 20 L/min were used in some of the early tests in order to determine the limits of detection and to evaluate breakthrough. For a 10-hour test, with a sample airflow rate of 10 L/min, the lower limit of detection of the individual PAHs ranged from 0.003 ng/m^3 for anthracene to 0.05 ng/m^3 for indeno [1,2,3-cd]pyrene. Under these test conditions, the lower limit of detection for benzo[a]pyrene was 0.01 ng/m^3 .

After the samples were collected, the sorbent tubes were refrigerated at 4 °C (39 °F) prior to extraction. At the time of extraction, one mL of internal standard solution in acetonitrile (described below) was added to each tube. All of the solvent was absorbed by the packing material. Tubes were Soxhlet extracted with methylene chloride for 20 h. The solvent was then evaporated, and 300 µL of hexane were added to yield approximately 400 µL of a 75% hexane/25% methylene chloride solution. The extract was pipetted onto an amino Sep-Pak solid-phase extraction cartridge (Waters, Bedford, MA) that had been pre-cleaned with a 2% methylene chloride/98% hexane solution. Analytes were eluted from the cartridge using two 10-mL portions of this methylene chloride/hexane solution. The solvent was evaporated and exchanged to acetonitrile; final sample volumes were approximately 300 µL. Samples were not allowed to evaporate to dryness during either stage of evaporation. Samples were placed in glass inserts in screw-capped amber autosampler vials, and were stored under refrigeration until analysis.

SRM 1597 (NIST, Standard Reference Material Program, Gaithersburg, MD), Complex Mixture of Polycyclic Aromatic Hydrocarbons from Coal Tar, was used as a quality control (QC) sample. A portion of the SRM, which is in toluene, was combined with a concentrated internal standard solution in hexane. The mixture was pipetted onto a pre-cleaned amino Sep-Pak cartridge, and analytes were eluted with 2% methylene chloride/98% hexane. The solvent was evaporated and exchanged to acetonitrile. The QC solution was stored in a volumetric flask in a refrigerator, and portions were withdrawn daily for analysis with the wood stove emission samples.

The liquid chromatograph (LC) was equipped with a Hypersil PAH analytical column (Serial No. 034552G, Keystone Scientific, Bellefonte, PA) which was held at 27 °C (80 °F) by a circulating water bath. A 0.5-mm stainless steel in-line frit protected the analytical column. Solvent A was 50% acetonitrile/50% water; solvent B was acetonitrile. The LC method consisted of a linear gradient that began with 100% A and went to 100% B in 50 min. The system was then returned to initial conditions over 5 min and was re-equilibrated for 10 min. The flow rate was 1.5 mL/min. A programmable fluorescence spectrometer (FS) was used to measure the PAHs using the wavelength program shown in Table 1.

The liquid chromatograph-fluorescence spectrometer (LC/FS) system was calibrated using eight calibration solutions. A series of four low-concentration and four high-concentration

calibration solutions, covering analyte ranges observed in six preliminary samples obtained during wood stove burns in the test house, were prepared from SRM 1647c (NIST, Standard Reference Material Program, Gaithersburg, MD), Priority Pollutants in Acetonitrile. Perylene, which is not included in SRM 1647c, was added to the low series of calibrants. Naphthalene-d_8 (Merck, Rahway, NJ, Lot 2068F), phenanthrene-d_{10} (Merck, Sharp, and Dohme [MSD], Rahway, NJ, Lot 109K), fluoranthene-d_{10} (MSD, Lot 2389J), and perylene-d_{12} (MSD, Lot 2310F) were used as internal standards.

Table 1 Programmed wavelength changes for the fluorescence detector and measured analytes

Time (min)	Excitation Wavelength (nm)	Emission Wavelength (nm)	Analytes
5	280	340	Naphthalene-d_8
			Naphthalene
11.9	249	362	Phenanthrene-d_{10}
			Phenanthrene
17	250	400	Anthracene
19	285	450	Fluoranthene-d_{10}
			Fluoranthene
22	333	390	Pyrene
25	285	385	Benz[a]anthracene
30.9	263	358	Chrysene
34.5	406	440	Perylene-d_{12}
			Perylene
39.5	296	405	Benzo[k]fluoranthene
			Benzo[a]pyrene
			Dibenz[a,h]anthracene
			Benzo[ghi]perylene
50.2	300	500	Indeno[1,2,3-cd]pyrene

Real-Time PAH and Building Pressures

A personal computer (PC) was used to monitor and record total polycyclic aromatic hydrocarbon concentrations and pressure differences across the test building walls and in the stove flue. This PC-based data acquisition system recorded voltages from the PAH monitor and pressure sensors through an interface box fabricated at NIST. The PAH measurements were made using an EcoChem Model PAS 1000i, Realtime Polycyclic Aromatic Hydrocarbon Analyzer for Combustion Aerosols (EcoChem, West Hills, CA). The analyzer senses PAHs with a photoelectric aerosol sensor that works on the principle of photoionization of carbon aerosols in the air sample using UV light. By choosing a specific wavelength of UV light at a low intensity, only carbon particles with PAHs on the surface emit electrons. The electrons are removed and the positively-charged particles are collected inside an electrometer where the charge is measured. The concentration of the PAHs in the air sample is proportional to the signal resulting from the measured charge. While PAHs exist in both particulate and vapor phases, the EcoChem

monitor detects only those PAHs in the particulate phase and does not differentiate between PAH species. The monitor was calibrated by the manufacturer using the average of several calibration curves from PAH sources such as combustion engines and oil burners. Assuming this curve is also representative of wood stove emissions, the lower limit of detection of the monitor is 10 ng/m^3 and the resolution is 7 ng/m^3.

The pressure differences across the exterior walls, and between the indoors and the interior of the stove flue, were measured using differential pressure transducers. Each of the transducers transmitted a 0-5 VDC signal to the data acquisition system. The transducers were calibrated by the manufacturer and zeroed after installation in the test house. The transducers used on the walls have a range of -25 to 25 Pa (-0.1 to 0.1 in of water), and the flue transducer has a range of -62.5 to 62.5 Pa (-0.25 to 0.25 in of water). The pressure transducers have an accuracy of 1% full scale. The wall pressure differences were measured 1.5 m (5 ft) above the floor and horizontally centered in each of the four walls. The flue transducer was installed approximately 1.8 m (6 ft) up from the floor in the middle of the back of the stove pipe to measure the pressure difference between the flue and the indoors. A negative pressure on the wall transducers corresponded to a lower pressure in the house than outside the house. A negative pressure on the flue transducer corresponded to a lower pressure in the flue relative to the pressure inside the house.

The data acquisition system monitored the PAH analyzer and differential pressure sensor output voltages every 5 s. At the end of 10 min, the measurements from the 5 channels were averaged and written to an ASCII file.

PM10

PM10 concentrations were measured using two aerosol samplers, each consisting of a particle impactor and a pumping unit. The pumping units contain a pump, a mass flow controller, a flow control circuit, and a timer. Two impactors can be connected to each pumping unit. The impactors are made of aluminum and consist of the inlet, the impaction stage, the body and the base. The impactors were configured to collect particles with aerodynamic diameters less than 10 μm. During sample collection, air flows into the inlet, through the nozzle, around the impaction plate, through the body and out the base. A 37-mm Teflon filter was placed in the base to collect the particles that flow around the impaction plate.

The PM10 sample pumps were calibrated prior to the wood stove tests with a bubble flow calibration device having an accuracy of 2% of the reading. During the tests, the pumps were set at 10 L/min, based on the calibrations. This airflow rate was verified during the tests by measuring and recording the voltage output of the mass flow meters. Long and short samples of the test house air and the outdoor air were collected. The long samples were started before the fire and were about 10 h in duration. The short samples were collected over about 8 h and were started after the second loading of wood. Two impactors were set up in the test house and two at an outdoor location. The two indoor impactors were located near the north wall sample point, as illustrated in Figure 2, about 1.2 m (4 ft) above the floor. The two outdoor impactors were located about 36 m (120 ft) south west of the house at a height of about 1.5 m (5 ft) above the ground. The filters were sent to a commercial laboratory to gravimetrically determine the particulate mass collected during the test.

Particle Counts

Particle counts were measured in six size ranges with a microprocessor-based airborne particle counter. The particles were sampled at the single indoor location shown in Figure 2. The particle counter incorporates an elliptical mirror system and employs the principle of wide-angle light scattering. When particles enter the particle sensing zone of the elliptical mirror, they scatter light to a photomultiplier tube, which in turn detects the light and converts it to an electrical signal. The magnitude of the signal is proportional to the size of the particle scattering the light. The system has a size sensitivity of 0.3 μm and a resolution of 0.02 μm. The counter was calibrated by the manufacturer prior to the wood stove tests and performs an automatic field calibration between each sample period. The six measured particle ranges were: 0.3-0.5 μm, 0.5-0.7 μm, 0.7-1.0 μm, 1-5 μm, 5-10 μm, and greater than 10 μm. The particle counter was programmed to count particles for 9 min and then delay for 1 min while the total particle counts of the six ranges were recorded. The particle counts were recorded in an ASCII file by a personal computer through an RS-232 serial port link between the computer and the particle counter. The recorded particle counts were converted to concentrations in units of number of particles per m^3 of air for each of the six size ranges. Hourly averages of these concentrations were then calculated.

Carbon Monoxide, Carbon Dioxide and Relative Humidity

Carbon monoxide (CO) and carbon dioxide (CO_2) concentrations and percent relative humidity (RH) were monitored and recorded by another computer-based data acquisition system. The system employed a computer-controlled multiposition valve to switch between sample locations and infrared absorption analyzers to monitor the CO and CO_2 concentrations. The CO monitor has a range of 0-50 parts per million (ppm) and is accurate to within 0.1 ppm. The CO_2 monitor has a range of 0-2500 ppm and is accurate to within 0.5% of full scale. The CO and CO_2 instruments were calibrated between each test, and the calibrations were checked during each test. The relative humidity sensors are bulk polymer resistance sensors with an accuracy of 3% of the reading. The relative humidity sensors were calibrated by the manufacturer and compared to other NIST-calibrated RH sensors.

CO and CO_2 concentrations were measured at the indoor north, south and west sampling locations, and at the outdoor north and west locations shown in Figure 2. The concentration monitors have continuous outputs, which were recorded at the end of each minute. Two consecutive one-minute measurements were made at each location and were recorded in an ASCII file. The relative humidity was measured at the north and south indoor sample locations. The outdoor RH was measured below the eave of the roof at the east end of the north wall. The average RH at each location was recorded in a ASCII file every 10 min. The CO/CO_2/RH system was generally run 24 h each day while the stoves were being tested. Hourly averages of the concentrations and RH were calculated from the recorded data.

Building Air Change Rate, Temperature and Wind Speed

Building air change rates (ach) were measured with an automated tracer gas decay system. This computer-based system consists of a tracer gas monitor and subsystems for tracer gas injection and air sampling. The system was also used to monitor indoor and outdoor temperatures, wind speed and wind direction. Sulfur hexafluoride (SF_6) was the tracer gas used in the tests. The SF_6 concentration was monitored with a gas chromatograph equipped with an electron capture detector. The system was calibrated before each test, and the calibration was checked during each test. The electron capture detector of the system was capable of determining SF_6 concentrations over a range of approximately 10 to 250 ppb with an accuracy of approximately 2%. The tracer gas injection subsystem employed a computer-controlled solenoid to inject SF_6 into the distribution duct of the forced-air furnace. The furnace fan was used to mix and distribute the tracer gas within the house. The air sampling subsystem consists of sample pumps used to pull air from the sample locations and a computer-controlled multiposition valve to switch between sample locations. The indoor and outdoor tracer gas sample locations were identical to those of the CO and CO_2 monitoring systems. The uncertainty of the measured air change rates is approximately 10% of the value.

The indoor and outdoor temperatures were measured with thermistors having an uncertainty of about 0.4 °C (0.7 °F). An anemometer was installed on the west exterior wall, approximately 2.0 m (6.6 ft) above the crest of the roof, to measure wind speed and direction. Interior temperatures were measured about 1.5 m (6 ft) above the floor and about 0.3 m (1 ft) out from the center of each wall as illustrated in Figure 2. The outdoor temperature was measured below the eave of the roof at the west end of the north wall. The temperature, wind speed and direction were measured every minute and recorded as hourly averages.

Wood Consumption

Before each test, approximately 12 pieces of wood were numbered, and the weight and moisture content (MC) of each piece was measured and recorded. The moisture content was measured in four places on each piece of wood using a moisture meter with a measurement range of 4.5% to 60% MC on a dry basis and a resolution of 0.1% MC. The wood scale has a range from 0-23 kg (0-50 lbs) and a resolution of 0.05 kg (0.1 lb). When wood was added to the stove, the time and identification numbers of the wood pieces were recorded.

Test Protocols

Two protocols were developed to insure consistent test procedures and data collection during stove tests. One protocol, titled Stove Operation Protocol, was developed for operating the wood stoves and is presented in Appendix A. The other, titled Instrumentation Protocol, was developed for the test equipment and is presented in Appendix B. This section describes both protocols.

Stove Operation

The Stove Operation Protocol describes the preparation of the test house, wood and stove prior to the tests, and the operation of the stove during the test. It also describes the "shut down" process at the end of the test and the procedure for cleaning the house between tests. On non-test days, the thermostat in the test house was set at 21 °C (70 °F). On the day before a test, one piece of wood was weighed and its moisture content was measured. The piece of wood was then split for kindling. Just prior to the test, 12 additional pieces of wood were numbered and weighed, and the moisture content of each piece was measured and recorded. The furnace thermostat was set to 15 °C (60 °F) and the fan was set for continuous operation. At the beginning of the test, the stove combustion air vent(s) and catalytic converter bypass damper (if present) were opened and three fire starters were placed in the stove with kindling loosely stacked on top. The fire starters were then lit, the stove door was closed, and the time and room temperature were recorded. The fire starters, approximately 2.5 cm^2 x 1 cm (1 in^2 x 3/8 in), were made of 10% recycled wood and unspecified substances designed to light easily and stay lit, to simplify the starting of wood fires. After the kindling was burning well, the stove door was opened about 1.5 cm (1/2 in) for 10 s, then slowly opened completely. This door opening procedure was employed to prevent smoke from entering the room from the stove due to opening the door too quickly. With the door open, two or three pieces of wood were added to fill the stove, the door was closed, and the numbers of the wood pieces were recorded along with the time, stove temperature and the room temperature. When the stove temperature reached 200 °C (400 °F), the vents were closed partially to keep the house temperature between 21 and 27 °C (70 and 80 °F). If the stove had a catalytic converter, it was also closed at this time. Once a base of coals was formed and the first load of wood was burned down to roughly one-quarter of the interior volume of the stove, the catalytic converter and the vents were opened, the door was opened about 1.5 cm (1/2 in) for 10 s, then opened all the way, and the stove was reloaded to full capacity. After reloading, the door was closed and the numbers of the loaded wood pieces recorded. The vents and the catalytic converter (if present) were closed when the stove temperature reached 200 °C (400 °F). The reloading process continued throughout the test. When the test was over, the vents and catalytic converter were opened fully.

During the test, the vents of the stove were closed if the room temperature rose above 27 °C (80 °F) and opened if the room temperature went below 21 °C (70 °F). Also, if the stove temperature dropped below 150 °C (350 °F) and had a catalytic converter, the converter was opened. If the stove rose above 200 °C (400 °F), the converter was closed. When the stove vents or catalytic converter were adjusted, the stove and room temperature, along with the adjustment, were recorded. On the day after a test, the stove's ash bin was emptied, leaving a bed of ashes about 2.5 cm (1 in) thick, and the house floor was swept and wet-mopped.

Instrumentation

The Instrumentation Protocol describes the preparation of the test equipment and data acquisition systems, the equipment operation and air sampling procedures during the test, and the procedure for equipment shut-down after the test. Tasks related to the test equipment between tests are also described. The protocol describes the procedure for starting and ending the long and short PM10 and PAH samples, mid-morning and mid-afternoon equipment checks, post-test activity and instrumentation checks, and calibrations on non-test days. At the beginning of a test, the operational status of each piece of equipment was checked and recorded. The tracer gas decay system operation was checked and critical parameters were recorded. Sample lines and pumps were also checked to insure they were connected and functioning properly. The indoor and outdoor SF_6, CO and CO_2 concentrations were examined to verify that they were within reasonable ranges. Next, the PAH concentrations and wall/flue pressures were examined to verify that the real-time PAH analyzer and pressure transducers were functioning properly. The operation of the particle counter system was also checked.

After these equipment checks, the PM10 and PAH sample pumps were started and the airflow rates were checked. After proper operation was verified and the PAH sample stands were set up, the pumps were turned off and the long PAH sample tubes and PM10 filters were labeled. The long PAH sample tubes were then connected to the sample lines, and the particulate filters were put in the PM10 impactors. The long PAH sample pumps and the PM10 pumps were then started, and the start times recorded along with the timer readings from the mass flow controller and elapsed time indicators in the PM10 pumping unit boxes. After the second loading of the stove with wood, the short PAH sample tubes and PM10 filters were labelled and installed, the short sample pumps were started, and the start times were recorded.

Three to four hours into each test, an equipment performance check was performed. The tracer gas system base and peak frequencies were checked and recorded, and the concentrations of selected SF_6 calibration gases were measured and recorded. The indoor and outdoor CO and CO_2 concentrations were checked to insure they were in a reasonable range, and the concentrations of selected calibration gases were measured and recorded. The PAH levels and wall pressures were checked to see that they were within expected ranges, and the particle counter display was checked to insure that the counts were being written to the personal computer. The inspection also involved checking and recording the DC voltages from the PM10 pumps and the airflow rates of the PAH pumps. About 3 h before the end of the test, another equipment check was performed which included all the tasks of the previous equipment check, with the exception that the SF_6, CO and CO_2 calibration gases were not sampled.

When the test was over, the PAH and PM10 pumps were turned off, the samples were collected, and the sample end-times were recorded. A post-test inspection of the operation of the equipment was then performed.

On non-test days, the tracer gas decay system was thoroughly checked to see that the sample injection time and the time the sample took to elute from the gas chromatographic column had not changed. The SF_6 detector was then calibrated. The pressure transducers were also rechecked and zeroed if needed, and the impactor pumping units were recalibrated.

RESULTS AND ANALYSIS

This section presents the results of the wood stove tests and the analysis of the measured data. The various tests are described first in terms of their duration, temperature conditions and fuel consumption. A table containing the detailed results of one test is presented. Similar tables for all tests are contained in Appendix C. The results of the PAH concentration measurements based on the sorbent tubes are then given. The analysis of these concentrations to determine indoor PAH emission rates and source strengths is described and these results are presented. Similarly, indoor CO emission rates and source strengths were determined and these results are presented.

Summary of Tests

Table 2 is a summary of the stove tests. It contains the test identification number (with the letter corresponding to the wood stove), the test date and duration, the average indoor-outdoor air temperature difference (ΔT) during the test, the mass of wood burned during the test, the percent moisture content (dry basis) of the wood burned, the number of times the stove was fueled, and the number of times the stove door was opened during the test. The duration of the test is the time from the start of the fire until it was burned out. The end time was determined by the static pressure measured in the stove flue. The mass of wood burned during the test includes the kindling, usually about 2.3 kg (5 lb). The number of stove door openings includes every time the door was opened to start the fire, load wood or tend the fire.

Table 2 Summary Table of Stove Tests

Test ID	Date	Duration (h)	ΔT (°C)	Wood burned (kg)	Moisture content (%)	Number of fuelings	Number of door openings
A.1	2/23/94	11.2	23.9	22.4	26	5	5
A.2	2/25/94	14.8	17.7	16.5	28	5	6
A.3	2/28/94	11.9	25.4	17.7	26	5	5
A.4	3/02/94	9.3	22.1	16.7	28	6	6
B.2	3/16/94	16.9	30.1	31.1	30	8	8
B.3	3/17/94	13.8	27.3	25.7	25	8	8
B.4	3/22/94	11.8	22.4	22.3	24	6	7
C.1	3/29/94	12.2	22.7	18.4	23	8	9
C.2	3/30/94	12.6	21.2	16.6	21	8	10
C.3	3/31/94	10.9	21.6	14.8	16	6	9
D.1	4/07/94	14.4	27.6	20.6	17	7	8
D.2	4/08/94	11.7	27.0	17.9	16	9	9
D.3	4/21/94	12.5	23.7	17.7	17	6	7
Blank Test, No Stove Operating							
E.1	4/22/94	12.3	13.2	0	---	0	0

The stove tests were performed between the end of February, 1994 and the third week in April. Three acceptable tests were performed on each stove, except for stove A, which was tested four times. As the test dates moved into the spring season, the tests on stoves B, C and D were conducted overnight. Testing at night increased the indoor-outdoor temperature difference and eliminated the solar load on the test house, thereby preventing overheating of the test house. A small number of tests were aborted or otherwise not included in the list due to instrumentation problems. Test E.1 was performed without a fire in the stove, but with all of the test instruments operating. The stove tests generally lasted 10 to 12 h, and the average indoor-outdoor temperature difference was generally 20 to 30 °C (36 to 54 °F). The number of door openings for stoves A and B were generally the same as the number of fuelings because the wood burned evenly and there was no need to tend the fire. However, the wood in stoves C and D did not burn completely without being rearranged periodically, and therefore the number of door openings is larger than the number of fuelings for these two stoves.

Test Results

Table 3 is a summary of the results of a typical stove test, specifically test C.1. Test result summary tables for all the tests are presented in Appendix C. The summary tables contain hourly average values for the following parameters: indoor and outdoor temperatures, wind speed, the difference between indoor and outdoor carbon monoxide concentrations, indoor and outdoor carbon dioxide concentrations, particle count concentrations for the six particle size ranges measured, flue and wall pressures, real-time total particulate-phase PAH concentrations and air change rates. The air change rates are two-hour averages. The fueling schedule is also given, containing the time and mass of each fuel loading. The start and stop times of the long and short PAH and PM10 samples are also contained in the table. The results of the PM10 measurements are presented in the table for the long and short samples of the indoor and outdoor air. These results include an estimate of the uncertainty in the particulate levels based on the uncertainties in the air sample volume and in the determination of the mass collected. The results of the PAH concentration measurements with the sorbent tubes are discussed in the next section.

Based on the objective of the study, the analysis of the test results concentrates on the determination of PAH emission rates as discussed in the next section. However, the test result summary tables contain a great deal of information. The increase in carbon monoxide concentrations in the test house during test C.1 is less than 1 ppm. In other tests, the indoor CO levels were 1 to 2 ppm above outdoors. Indoor carbon dioxide concentrations were significantly higher than outdoors, but this was due primarily to the presence of people in the test house and not to the stove operation. The flue and wall pressures show the impact of the stove operation. During the fires the flue pressure is about 10 Pa below the pressure in the house, and the house pressure is about 1 Pa lower than outside. The total PAH concentrations from the real time monitor are variable during the tests, depending on whether the stove door was open during a given hour. The maximum concentrations also vary widely between tests from tens to thousands of ng/m^3. In test C.1, the first air change rate was determined for a two-hour period before the test started and is lower than the air change rates measured during the test. An increased air change rate during stove operation was observed in all tests due to the pressures induced by the stove. The increase in the air change rate varied among the tests, but generally ranged from 0.1 to 0.2 h^{-1}. The measured PM10 concentrations in test C.1 are higher indoors than outdoors, and this is true for most of the other tests as well. However, the difference between the indoor and outdoor concentrations is variable among the tests, and in some tests the concentrations are essentially the same. In most tests, the outdoor concentration is not significantly different from zero.

Summary of Results of Stove Test C.1

HOURLY AVERAGE DATA

Hour	Tin (°C)	Tout (°C)	Wind Speed (m/s)	In - Out CO (ppm)	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	Particle Count Concentration Number of Particles/m^3 .3-.5	.5-.7	.7-1.0	1-5	5-10	>10	Pressure Flue (Pa)	Pressure Wall (Pa)	Total PAH EcoChem (ng/m^3)	ACH (h^{-1})
1800	21.9	6.8	0.4	---	---	---	8.00E+06	5.98E+05	1.05E+05	2.66E+04	1.03E+02	4.77E+01	-0.05	-0.02	---	---
1900	20.8	5.8	0.2	0.0	442	393	6.89E+06	4.72E+05	9.17E+04	2.41E+04	4.72E+01	2.19E+01	0.09	0.00	---	0.29
2000	20.0	4.5	0.3	0.0	442	400	6.17E+06	4.99E+05	1.52E+05	6.12E+04	2.02E+03	9.48E+02	-0.03	0.01	0	---
2100	19.6	4.6	0.4	0.2	598	390	1.03E+07	2.11E+06	9.32E+05	4.38E+05	1.15E+04	5.66E+03	-7.76	0.64	9	---
2200	22.4	4.7	0.7	0.3	646	385	1.79E+07	3.05E+06	4.53E+05	1.40E+05	2.00E+03	9.38E+02	-12.30	0.13	15	0.45
2300	25.8	4.0	0.5	0.3	729	386	1.36E+07	2.60E+06	9.75E+05	4.11E+05	5.10E+03	2.42E+03	-13.25	-0.16	1	---
0000	26.7	3.0	0.3	0.4	958	388	1.56E+07	3.28E+06	1.15E+06	4.98E+05	6.73E+03	3.27E+03	-14.94	-0.38	5	0.40
0100	29.9	2.3	0.5	0.4	1047	383	1.32E+07	2.35E+06	1.02E+06	4.21E+05	3.98E+03	1.93E+03	-15.02	-0.46	2	---
0200	28.7	2.0	0.5	0.5	1019	377	9.79E+06	1.38E+06	5.09E+05	1.86E+05	2.09E+03	9.81E+02	-11.79	-0.46	0	---
0300	26.6	2.1	0.5	0.4	1132	372	1.19E+07	4.41E+06	2.32E+06	1.12E+06	2.28E+04	1.09E+04	-12.03	-0.35	1	0.47
0400	26.6	2.3	0.5	0.4	1189	367	1.11E+07	2.54E+06	8.62E+05	3.05E+05	3.52E+03	1.79E+03	-10.93	-0.28	4	---
0500	25.0	2.4	0.5	0.3	1018	363	2.14E+07	5.23E+06	7.84E+05	2.26E+05	2.70E+03	1.36E+03	-12.00	-0.28	16	0.37
0600	28.6	2.2	0.5	0.4	971	364	2.91E+07	9.88E+06	5.38E+06	3.01E+06	3.35E+04	1.52E+04	-15.81	-0.35	7	---
0700	27.7	3.7	0.6	0.3	1093	361	2.21E+07	1.24E+07	7.59E+06	3.63E+06	2.57E+04	1.15E+04	-12.14	0.13	0	---
0800	26.1	5.7	0.7	0.3	813	356	1.10E+07	2.70E+06	1.01E+06	2.43E+05	6.05E+02	2.55E+02	-7.77	0.23	0	---
0900	24.7	7.3	0.8	0.3	660	356	6.50E+06	9.05E+05	2.41E+05	4.54E+04	3.63E+02	1.50E+02	-5.17	0.38	---	---

FUEL CONSUMPTION

EVENT	TIME	LOAD (kg)
Start of fire	2114	1.56
First Loading	2119	3.46
Second Loading	2148	1.96
Third Loading	2343	4.13
Fourth Loading	0102	0.65
Fifth Loading	0300	1.84
Sixth Loading	0427	2.94
Seventh Loading	0450	1.83

SAMPLING TIMES	
Start of long samples	2054-2104
Start of short samples	2159-0005
End of long and short samples	0613-0630

PM10 RESULTS ($\mu g/m^3$)

SAMPLE	CONCENTRATION	UNCERTAINTY
In-long	56	13
In-short	84	22
Out-long	9	4
Out-short	7	5

Figure 4 is a plot of the response of the real-time PAH monitor during test D.3. This plot shows the typical course of PAH concentrations during a stove test. The times of the start of the fire and the fuel loadings are identified in the figure. A peak in the indoor PAH concentration occurs when the stove door is opened to start or fuel the fire. The first peak was the largest because it includes the cumulative effect of three door openings over a 20 min period. The first door opening was to start the kindling, the second to fuel the stove with the first load of wood, and the third to fuel the stove with the second load of wood. The minimum concentration between peaks can not be seen in the figure, but it was generally between 0 and 10 ng/m^3. Despite the care taken when opening the stove door, smoke still entered the interior volume of the test house, increasing the indoor PAH concentration in this test by a factor of about 100.

PAH Measurements with Sorbent Tubes

This section presents and discusses the results of the PAH concentration measurements with the sorbent tubes. The concentrations themselves are presented first, followed by an analysis of these concentrations to determine indoor PAH emissions rates and source strengths.

PAH Concentrations

Average PAH concentrations were determined from the PAH mass collected on the sorbent tubes and the sample air volume. Table 4 contains the measured PAH concentrations from the indoor and outdoor long and short samples for all of the tests which were not aborted or eliminated due to instrumentation problems. These concentrations were determined by subtracting the mass of each compound on the blank tube for each test from the mass on the sample tube. The resultant mass was then divided by the sample volume to yield the concentration of each compound in units of ng/m^3. In tests A.4 and D.1, the sample blanks were not used due to analysis problems, and the average of all the other blanks was used as the blank values in the analysis of these tests.

Table 4 lists PAH compounds from benz[a]anthracene to indeno[1,2,3-cd]pyrene, because these compounds were of most interest to CPSC in their risk assessment and because the concentrations of the lower molecular weight compounds were relatively high in the no-stove test E.1. The table also contains the total PAH concentration for the eight compounds listed in the table. In this table B[a]A = benz[a]anthracene, CHRYS = chrysene, PERY = perylene, B[k]F = benzo[k]fluoranthene, B[a]P = benzo[a]pyrene, DB[ah]A = dibenz[a,h]anthracene, B[ghi]p = benzo[ghi]perylene and INDEN = indeno[1,2,3-cd]pyrene. The entries denoted with the symbol * correspond to negative concentration values after the blank was subtracted, 0.0 entries correspond to values less than 0.05 after subtraction of the blank, and no entry corresponds to cases where the compound was not detected. Appendix D contains the measured PAH concentrations for all thirteen compounds that were analyzed. Table 4 shows that the outdoor PAH concentrations were higher than the corresponding indoor concentrations during some tests, presumably due to local wind patterns directing the flue gas towards the outdoor sampling location.

The precision of these concentrations was estimated based on an analysis of the duplicate samples, which revealed that a common within-duplicate precision was reasonable for the total PAH concentrations. Based on this assumption, the 95% confidence interval of the mean of duplicate total PAH concentrations is estimated to be 1.0 ng/m^3. In some cases, this value of the

uncertainty is larger than the mean value itself. When there is only one sample (no duplicate), the 95% confidence interval of the total PAH concentration is estimated to be 1.4 ng/m^3. This estimate is based on the assumption that the variability of the duplicate pairs also applies to the measured values in which there was no duplicate. The analysis of the duplicate B[a]P concentrations revealed that it was not reasonable to assume a common within-duplicate precision. However, the relative standard deviation was fairly common across pairs. Therefore, the 95% confidence interval for the mean of duplicate B[a]P concentrations is estimated to be 20% of the mean concentration. In cases in which there is only one sample (no duplicate), the 95% confidence interval of the B[a]P concentration is estimated to be 29% of the concentration.

Table 4 Summary of PAH Concentrations from Sorbent Tubes

Test	Sample	B[a]A (ng/m^3)	CHRYS (ng/m^3)	PERY (ng/m^3)	B[k]F (ng/m^3)	B[a]P (ng/m^3)	DB[ah]A (ng/m^3)	B[ghi]P (ng/m^3)	INDENO (ng/m^3)	Total (ng/m^3)
A.1	In-Long	*	*	0.7	0.9	0.7		2.4		4.7
	In-Long	*	0.4	0.5	0.3	0.5	0.1	0.8	0.5	3.1
	In-Short	*	1.4	1.0	0.3	0.5	*	0.9	1.1	5.2
	In-Short	0.0	0.3	1.0	0.3	0.4	*	1.5		3.5
	Out-Long	*	*	0.4	0.4	0.2				1.0
A.2	In-Long	0.5	1.8	0.1	0.5	0.8	0.5	0.8	0.5	5.5
	In-Long	0.9	2.6	0.1	0.5	0.8	0.6	0.9	0.6	7.0
	In-Short	*	0.3	*	0.2	0.2	0.3	0.4	0.4	1.7
	In-Short	0.3	1.5	0.0	0.1	0.2	0.4	0.2	0.3	3.0
	Out-Long	*	0.3	0.1	0.3	0.5	0.1	0.4	0.6	2.3
	Out-Short	0.0	0.7	0.1	0.5	0.7	0.2	0.4	0.5	3.1
A.3	In-Long	*	0.5	0.0	0.3	0.6	0.3	0.6	0.8	3.1
	In-Long	*	1.0	0.1	0.4	0.7	0.1	0.5	0.9	3.7
	In-Short	*	0.6	0.0	0.2	0.5	0.1	0.7	0.9	2.9
	In-Short	*	0.8	0.0	0.3	0.6	0.1	0.7	0.9	3.3
	Out-Long	0.5	0.4	0.0	0.2	0.2	0.0	0.1	0.2	1.6
	Out-Short	0.0	0.4	*	0.1	0.1	0.0	0.3	0.2	1.1
A.4	In-Long	*	0.1	0.1	0.1	0.2	*	0.1	0.3	0.9
	In-Long	*	0.1	0.0	0.1	0.2	*	0.0	0.2	0.7
	In-Short	0.1	0.0	0.0	0.1	0.2	*	0.0	0.2	0.6
	In-Short	0.0	0.4	0.0	0.1	0.2	*	0.0	0.3	1.0
	Out-Long	0.0	0.1	0.1	0.2	0.2	*	0.5	0.3	1.4
	Out-Short	*	*	0.1	0.1	0.1	*	*	0.2	0.5
B.2	In-Long	0.3	1.9	0.3	0.6	1.5	0.5	1.4	1.8	8.4
	In-Long	0.3	1.9	0.3	0.6	1.4	0.5	1.2	1.2	7.3
	In-Short	0.3	1.6	0.1	0.2	0.5	0.1	0.6	0.7	4.0
	In-Short	0.1	1.4	0.1	0.2	0.3	0.2	0.5	0.4	3.1
	Out-Long	0.0	0.2	0.1	0.1	0.2	0.0	0.2	0.2	0.9
	Out-Short	0.0	0.2	0.1	0.1	0.1				0.4
B.3	In-Long	0.4	1.5	0.0	0.1	0.2	0.1	0.2	0.5	3.0
	In-Long	0.3	1.4	0.1	0.1	0.2	0.1	0.4	0.4	3.0
	In-Short	0.2	1.2	0.0	0.1	0.1	0.1	0.3	0.2	2.3
	In-Short	0.2	0.8	0.0	0.1	0.1	0.1	0.5	0.2	2.0
	Out-Long	0.3	1.1	0.1	0.4	0.6	0.3	0.6	0.3	3.6
	Out-Short	0.4	0.7	0.1	0.3	0.4	0.1	0.4	0.3	2.7
B.4	In-Long	*	1.4	0.0	0.1	0.2	0.1	0.2	0.1	1.9
	In-Long	*	0.3	0.1	0.1	0.1	0.0	0.1	0.2	0.8
	In-Short	*	0.4	0.0	0.1	0.1	0.1	0.1		0.9
	In-Short	*	0.1	0.0	0.1	0.1	0.1	0.1		0.5
	Out-Long	*	0.0	0.1	0.3	0.4	0.1	0.6	0.3	1.7
	Out-Short	*	0.1	0.1	0.3	0.4	0.1	0.8	0.5	2.1

Test	Sample	B[a]A (ng/m^3)	CHRYS (ng/m^3)	PERY (ng/m^3)	B[k]F (ng/m^3)	B[a]P (ng/m^3)	DB[ah]A (ng/m^3)	B[ghi]P (ng/m^3)	INDENO (ng/m^3)	Total (ng/m^3)
C.1	In-Long	0.5	0.7	0.0	0.1	0.2	*	0.3	0.7	2.4
	In-Long	0.3	0.7	0.0	0.1	0.1	*	0.3	0.1	1.5
	In-Short	0.4	1.4	0.2	0.1	0.1	*	0.1	0.2	2.5
	In-Short	0.2	1.2	0.0	0.1	0.2			0.1	1.8
C.2	In-Long	0.1	0.9	0.1	0.1	0.2	0.7	0.3		2.5
	In-Long	0.2	1.4	0.1	0.1	0.2	0.8	0.5	0.2	3.6
	In-Short	0.1	1.0	0.1	0.1	0.2	0.8	0.4	0.3	3.0
	In-Short	*	0.8	0.1	0.3	0.2	0.1	0.2		1.6
	Out-Long	0.1	1.7	0.3	0.7	1.3	0.4	1.3		5.8
	Out-Short	0.1	1.9	0.4	0.7	1.4	0.3	1.4	1.3	7.5
C.3	In-Long	*	1.0	0.1	0.1	0.1				1.3
	In-Long	*	1.0	0.1	0.1	0.1	0.0	0.1		1.4
	In-Short	*	0.2	0.2	0.1	0.1	0.1	0.2		0.8
	In-Short	*	1.1	0.1	0.1	0.1	0.1	0.1		1.6
	Out-Long	*	0.2	0.2	0.2	0.1		0.3	0.2	1.2
	Out-Short	*	0.0	0.1	0.1	0.2				0.4
D.1	In-Long	0.1	2.1	0.1	0.1	0.3	0.0	0.1	0.5	3.3
	In-Long	0.0	3.7	0.1	0.1	0.3	*	0.2	0.3	4.9
	In-Short	*	1.6	0.0	0.1	0.2	*	0.0	0.3	2.2
	In-Short	0.1	2.0	0.0	0.1	0.2	*	0.0	0.7	3.1
	Out-Long	*	*	0.0	0.1	0.1	*	0.0	0.2	0.4
	Out-Short	0.1	*	0.0	0.1	0.1				0.3
D.2	In-Long	1.1	2.3	0.1	0.1	0.2	1.0	0.4	0.4	5.6
	In-Long	1.0	3.0	0.1	0.1	0.2	0.9	0.3	0.2	5.9
	In-Short	0.9	2.7	0.1	0.1	0.2	1.0	0.2		5.1
	In-Short	0.9	2.4	0.1	0.1	0.1	0.8	0.3	0.5	5.1
	Out-Long	*	0.6	0.1	0.2	0.2	0.7	0.4		2.1
	Out-Short	0.1	0.4	0.1	0.1	0.1	0.7	0.2		1.8
D.3	In-Long	1.1	3.7	*	0.2	0.4	0.1	0.4	0.6	6.4
	In-Long	1.4	3.5	*	0.2	0.3	0.1	0.3	0.5	6.4
	In-Short	0.7	2.8	*	0.1	0.1	0.1	0.3	0.3	4.4
	In-Short	1.0	3.0	*	0.1	0.1	0.1	0.3	0.2	4.8
	Out-Long	0.3	0.2	*	0.1	0.1				0.6
	Out-Short	1.1	0.4	*	0.1	0.1				1.6
E.1	In-Long	0.4	0.8	0.0	0.0	0.0				1.3
	In-Long	0.1	0.9	0.0						1.0
	In-Short	0.1	0.7	0.1	0.0	0.0				1.0
	Out-Long	0.3	0.1	0.0	0.0	0.0	0.0	0.2	0.3	1.0
	Out-Short	0.4	0.1	0.1	0.0					0.6

PAH Emission Rates

In order to generalize the measured PAH concentrations in the test house to situations in buildings with different air change rates and interior volumes and with different rates of wood consumption, it is necessary to compute PAH emission rates and source strengths from the test results. In the analysis that follows, the term emission rate refers to the mass of PAH emitted per unit time, and the term source strength refers to the mass of PAH emitted per mass of wood burned. These emission rates, in units of ng/s, and source strengths, in units of ng/kg of wood burned, are obtained by performing a single-zone mass balance analysis on the test house. The single-zone mass balance equation, in its instantaneous form, is given as:

$$V\frac{dC_{in}}{dt} = E + PQC_{out} - QC_{in} - kVC_{in} \quad (1)$$

where

V = test house volume (m^3)
C_{in} = indoor concentration of total or individual PAH (ng/m^3)
E = total or individual PAH emission rate (ng/s)
P = penetration factor for outdoor total or individual PAH
Q = airflow rate of outdoor air into the test house (m^3/s)
C_{out} = outdoor concentration of total or individual PAH (ng/m^3)
k = indoor decay rate of total or individual PAH (s^{-1})

The objective of these tests was to determine PAH emission rates and source strengths based on the concentrations measured with the long and short sorbent tubes. However, since these concentrations are averages over a period of several hours, the instantaneous form of the mass balance equation cannot be used. Instead, the mass balance equation is integrated with respect to time to yield the following equation:

$$V(C_{final} - C_{initial}) = \bar{E}T + P\bar{Q}\bar{C}_{out}T - \bar{Q}\bar{C}_{in}T - kV\bar{C}_{in}T \quad (2)$$

where

C_{final} = the indoor total or individual PAH concentration at the end of the sampling period (ng/m^3)
$C_{initial}$ = the indoor total or individual PAH concentration at the beginning of the sampling period (ng/m^3)
T = the duration of the sampling period(s)

The quantities with an overbar (e.g., $\bar{E}$) are the average values of the respective quantity over the sampling period. Equation 2 is based on an assumption that P and k are constant throughout the sampling period. Also, the indoor PAH concentration is assumed to be uniform within the test house. The average values of the products QC_{out} and QC_{in} are approximated by the product of their averages. Equation 2 can be solved for the average emission rate during the sampling period as follows,

$$\bar{E} = V\frac{\Delta C}{T} + \bar{Q}\bar{C}_{in} + kV\bar{C}_{in} - P\bar{Q}\bar{C}_{out} \qquad (3)$$

where ΔC equals C_{final} minus $C_{initial}$. The average emission rate can then be divided by the average rate of wood consumption for the corresponding time period to yield the average PAH (total or individual) source strength over the same time period per kilogram of wood burned.

Steady-state mass balance approaches have been used previously to determine emission rates and source strengths (Knight and Humphreys 1985, Sheldon et al. 1993b, Traynor et al. 1987). In these efforts, the PAH concentration was assumed to be at steady-state, and the term containing ΔC in Equation 3 was neglected. Depending on the stove operation at the beginning and end of the sampling period, it may be inappropriate to neglect this term.

Equation 3 was used to determine the emission rates and source strengths of B[a]P and total PAH, where total PAH is the sum of the concentrations of the eight individual compounds in Table 4. Several key parameters are required to use Equation 3 to determine these emission rates: ΔC for B[a]P and total PAHs, the indoor decay rate k for B[a]P and total PAHs, the penetration factor P for B[a]P and total PAHs, and the average rate of wood consumption during the long and short sampling periods. The value of ΔC can not be determined directly for B[a]P and total PAHs, because only average values of these concentrations were determined with the sorbent tubes. Instead, an approximate value of ΔC was obtained based on the output of the real-time PAH monitor used in these tests. To estimate the value of ΔC for the total PAHs over a sampling period, the ratio of the total PAH concentration determined with the sorbent tube to the average concentration from the real-time PAH monitor over the period was determined. This ratio β_{total} is defined as

$$\beta_{total} = \frac{\text{Total PAH concentration from sorbent tube}}{\text{Average PAH concentration from real-time monitor}}. \qquad (4)$$

The concentration from the real-time PAH monitor at the end of the sampling period was then subtracted from the concentration from the monitor at the beginning of the sample period. This difference was then multiplied by β_{total} to estimate ΔC for the total PAH concentration.

To estimate the value of ΔC for B[a]P over a sampling period, the ratio of the B[a]P concentration determined with the sorbent tube to the average concentration from the real-time PAH monitor over the period was determined. This ratio $\beta_{B[a]P}$ is defined as

$$\beta_{B[a]P} = \frac{\text{B[a]P concentration from sorbent tube}}{\text{Average PAH concentration from real-time monitor}}. \qquad (5)$$

The concentration from the real-time PAH monitor at the end of the sampling period was then subtracted from the concentration from the monitor at the beginning of the sample period. This difference was then multiplied by the ratio $\beta_{B[a]P}$ to estimate ΔC for B[a]P.

The indoor decay rate k accounts for the loss of indoor PAHs through mechanisms other than dilution with outdoor air, primarily deposition on interior surfaces. The value of k for the test house was obtained by calculating a PAH decay rate based on the concentration determined with the real-time PAH monitor and comparing this value to the decay of the sulfur hexafluoride (SF_6). The PAH decay rate was determined on several occasions, when the indoor concentration had become elevated after the stove door was opened. The SF_6 decay rate for the same time period was then subtracted from the real-time PAH decay rate. Twelve such decay rate comparisons were made, and the results are presented in Table 5 in units of h^{-1}. This table includes two results from test A.5, however, PAH emission rates are not reported for this test due to data collection problems. The average value of k for these twelve decays is 3.47×10^{-4} s^{-1} (1.25 h^{-1}). This value was used for both the total PAH and B[a]P emission rate and source strength calculations. This compares to values of k of 0.14×10^{-4} s^{-1} (0.05 h^{-1}) used by Knight and Humphreys (1985) and 0.22×10^{-4} s^{-1} (0.08 h^{-1}) used by Traynor et al. (1987). The value used by Knight and Humphreys is presented with no explanation, however the value used by Traynor was determined in a test house by comparing measured particle decay rates with measured carbon monoxide decay rates. However, the particle decay rates were based only on particles with diameters of 0.6 μm or less and there were no mixing fans operating in the house at the time. The values presented in Table 5 are larger due to the existence of particles with diameters larger than 0.6 μm and the operation of a ducted mixing fan during the tests.

Table 5 Summary of PAH Decay Tests

Decay Test #	Stove Test #	Decay Rate (h^{-1}) PAH	Decay Rate (h^{-1}) SF_6	PAH Decay Rate k (h^{-1})
1	A.1	1.30	0.35	0.95
2	A.2	1.79	0.42	1.37
3	A.2	1.84	0.22	1.62
4	A.4	1.07	0.27	0.80
5	A.5	1.55	0.64	0.91
6	A.5	1.48	0.47	1.01
7	B.1	2.14	0.58	1.56
8	B.3	1.97	0.39	1.58
9	C.3	1.15	0.34	0.81
10	D.1	2.22	0.50	1.72
11	D.1	1.68	0.16	1.52
12	D.1	1.69	0.54	1.15
			Average	1.25
			Standard Deviation	0.35

A penetration factor P of 0.5 was used in these analyses for both B[a]P and total PAHs. This is the same value used by Knight and Humphreys (1985). It is also close to the average value of P (0.48) determined by Traynor et al. (1987) for several individual PAH compounds. Because of the relatively low outdoor PAH concentrations in most tests, the value of P is not critical to the mass balance analysis.

The average wood consumption rates for the long and short sampling periods were determined based on the time and mass of the individual fuel loadings. The mass of each fuel loading is designated as M_i. The average wood consumption rate for the long sample $\dot{M}_L$ was determined by dividing the total mass of the wood consumed by the length of time T_L from the beginning of the test to the time that the fire burned out. If there were N fuel loadings during the test, then $\dot{M}_L$ is given by the equation:

$$\dot{M}_L = \frac{1}{T_L} \sum_{1}^{N} M_i. \qquad (6)$$

The average wood consumption rate for the short sampling period is based on the mass of wood consumed starting with the load before the start of the short sampling period. The fuel loaded just prior to the start of the short sampling period is designated as M_s. T_s is the length of time between this fuel loading and the end of the fire. The average wood consumption rate during the short sampling period $\dot{M}_s$ is given by the equation:

$$\dot{M}_s = \frac{1}{T_s} \sum_{s}^{N} M_i. \qquad (7)$$

The values of C_{in} and C_{out} used in Equation 3 were obtained from Table 4. The value of Q was based on the average air change rate during the appropriate sample period (long or short) multiplied by the volume of the test house.

Based on the uncertainty in the estimate of the storage term in Equation 3, $V\Delta C/T$, only those tests for which this term is less than 10% of the calculated value of E are reported.

Figures 5 through 8 show the calculated emission rates in units of ng/s and source strengths in units of ng/kg of wood burned for B[a]P and total PAHs. These graphs show the results for all the tests that were acceptable in terms of the errors associated with the storage term and other considerations. The duplicate sample results for both the long and short samples are displayed in the graphs. Figure 5 shows the emission rate of total PAHs in units of ng/s, and Figure 6 shows the total PAH source strength in units of ng/kg of wood. The precision of these emission rates and source strengths was estimated based on an analysis of the duplicate samples. This analysis revealed that a common within-duplicate precision was reasonable for the total PAH emission rates and source strengths. Based on this assumption, the 95% confidence intervals of the mean of duplicate total PAH emission rate and source strength are estimated to be 0.04 ng/s and 95 ng/kg of wood burned, respectively. When there is only one sample (no duplicate), the 95% confidence intervals of the total PAH emission rate and source strength are estimated to be 0.06 ng/s and 138 ng/kg. As was the case for the concentrations, these single-sample estimates of the confidence intervals are based on the assumption that the variability of the duplicate pairs also applies to the measured values in which there was no duplicate.

Figure 7 shows the emission rate of B[a]P in units of ng/s, and Figure 8 shows the B[a]P source strength in units of ng/kg of wood. The analysis of the duplicate B[a]P emission rates and source strengths revealed that it was not reasonable to assume a common within-duplicate precision. However, the relative standard deviation was consistent across pairs. The 95% confidence interval for the mean of duplicate B[a]P emission rates and source strengths are estimated to be 28% of the mean value for emission rates as a function of time and for source strengths as a function of wood burned. In cases in which there is only one sample (no duplicate), the 95% confidence intervals of the B[a]P emission rates and source strengths are estimated to be 39% of the mean value.

An analysis of variance was performed to examine the variation in emission rate and source strength as a function of stove type, long versus short samples, numbers of fuelings and number of stove door openings. The results of this analysis revealed that while there was a statistically significant difference between the results of the individual tests, there was no statistically significant effect of any of the parameters examined (stove type, sample length, number of fuelings and number of stove door openings) on the measured emission rates and source strengths. The only exception is that there is a statistically significant difference among the stoves (A, B, C and D) in the B[a]P emission rates.

Given the lack of any significant effect of the parameters mentioned above, the mean emission rate and source strength was calculated for each test and the results are presented in Tables 6 and 7. These tables include only those tests for which there is more than one value from which to calculate the mean. Table 6 contains the mean emission rate for total PAHs in units of ng/s and source strength in units of ng/kg of wood burned. Table 7 contains the mean emission rates and source strengths for B[a]P. The means are presented with the uncertainty expressed as the 95% confidence intervals, which in turn depend on the number of values used to determine the mean. The values of the uncertainty in the emission rate and source strength of total PAHs in Table 6 are only a function of the number of values used to determine the mean and are large relative to the lower emission rates. For example, in test B.4 the uncertainty is essentially equal to the mean. The uncertainty for the emission rates and source strengths of B[a]P in Table 7 is a percentage of the mean value, and again depends on the number of values used to determine the mean. These uncertainties are between 25% and 35% of the mean value.

Referring to Table 6, the emission rate of total PAHs ranges from 0.03 to 0.24 ng/s. The mean value is 0.13 ng/s, and the median value is 0.12 ng/s. The source strength relative to the wood burning rate ranges from 67 to 711 ng/kg of wood burned. The mean value is 360 ng/kg, and the median is 332 ng/kg. The emission rates for B[a]P in Table 7 range from 0.003 to 0.028 ng/s, with a mean value of 0.012 ng/s and a median of 0.009 ng/s. The B[a]P source strengths relative to the wood burning rate range from 7 to 90 ng/kg. The mean value is 32 ng/kg, and the median is 22 ng/kg. For comparison, a paper by Traynor et al. (1987) reported B[a]P emission rates for seven tests of airtight wood stoves. The distribution of these emission rate values is skewed by one high value, so the mean value is not an appropriate summary statistic. The emission rates of B[a]P in this earlier study range from 0.006 to 0.211 ng/s, and the median is 0.011 ng/s. Accounting for wood burning rates, the source strengths in the Traynor study range from 8 to 174 ng/kg with a median value of 22 ng/kg. The B[a]P emission rates and source strengths reported in the NIST study are similar to the values reported in this previous study.

Table 6 Mean Emission Rates and Source Strengths of Total PAHs

Stove Test	Emission Rate (ng/s)	Uncertainty (ng/s)	Source Strength (ng/kg wood)	Uncertainty (ng/kg wood)
A.1	0.16	0.03	332	69
A.2	0.22	0.04	711	97
A.3	0.12	0.03	357	69
B.2	0.12	0.04	283	97
B.3	0.09	0.03	192	69
B.4	0.03	0.03	67	69
C.2	0.09	0.04	249	97
C.3	0.05	0.03	144	69
D.1	0.14	0.03	374	69
D.2	0.22	0.03	639	69
D.3	0.24	0.04	615	97

Table 7 Mean Emission Rates and Source Strengths of B[a]P

Stove Test	Emission Rate (ng/s)	Uncertainty (ng/s)	Source Strength (ng/kg wood)	Uncertainty (ng/kg wood)
A.1	0.020	0.006	41	10
A.2	0.028	0.012	90	32
A.3	0.023	0.007	66	17
A.4	0.008	0.002	16	6
B.2	0.013	0.006	31	11
B.3	0.006	0.003	11	3
B.4	0.003	0.001	7	2
C.3	0.004	0.001	11	3
D.1	0.010	0.003	27	7
D.2	0.006	0.002	16	4
D.3	0.013	0.006	33	12

Carbon Monoxide Emission Rates

Emission rates were also calculated for carbon monoxide using Equation 3. In these calculations, the penetration factor for CO was assumed to equal 1.0 and the decay factor k was assumed to equal 0. Table 8 presents the emission rates and source strengths for those tests for which they could be determined in units of μg/s and in mg/kg of wood burned, along with the uncertainties in their values. The uncertainties are generally about 20 to 35% of the calculated value, except for very low emission rates and sources strengths (Tests C.1 and C.3) in which the uncertainty is similar in magnitude to the emission rates and source strengths themselves. The mean source strengths and emission rates in Table 8 are 12 μg/s and 36 mg/kg of wood burned. Traynor et al. (1987) reports CO emission rates for seven airtight wood stoves that range from 3 to 46 μg/s, with a mean value of 23 μg/s. Accounting for wood burning rates, the source strengths in the Traynor study range from 5 to 90 mg/kg with a mean value of 38 mg/kg. The CO source strengths, based on wood burning rates, are very similar between the NIST and the Traynor studies.

Table 8 Mean Emission Rates and Source Strengths of Carbon Monoxide

Stove Test	Emission Rate (μg/s)	Uncertainty (μg/s)	Source Strength (mg/kg wood)	Uncertainty (mg/kg wood)
A.2	18	4	62	16
A.3	26	4	86	17
A.4	8	2	19	6
B.2	10	3	22	8
B.3	18	6	40	15
C.1	3	4	9	12
C.3	4	5	12	15
D.1	13	5	38	16
D.2	11	6	34	19

SUMMARY AND DISCUSSION

In order to support a cancer risk assessment being performed by CPSC on wood stoves meeting the EPA Phase II emission requirements, indoor PAH emission rates were measured for four stoves. During the tests, the stoves were operated in a manner consistent with typical residential use and in accordance with the manufacturers' instructions. Emission rates and source strengths were determined for B[a]P and total PAHs, where this total included 8 compounds with retention times between that of benz[a]anthracene and indeno[1,2,3-cd]pyrene under the conditions of chromatography described previously. Based on three tests on each of the four stoves, the average B[a]P emission rate is 0.012 ng/s and the average total PAH emission rate is 0.13 ng/s. Normalizing for the rate of wood consumption during each test, the average B[a]P source strength is 32 ng/kg of wood burned and the average PAH source strength is 360 ng/kg of wood. No statistically significant relationship was found between the measured emission rates or source strengths and the stoves (A, B, C and D), length of sampling period, number of fuelings or number of stove door openings. It may be that the variation in the emission rate and source strength among the tests is due to the manner in which the stove was operated, specifically the care in opening the stove door and vents. In these tests, great care was taken when opening the door to minimize the release of wood smoke to the indoors, and in many cases the release was minimal. In other cases, despite the care taken, a significant quantity of wood smoke was released to the indoors. In actual residential buildings, the indoor PAH emissions from a stove will presumably be more variable due to differences in use patterns in among residences and variations in the care taken by the occupants in opening the stove door. Another factor affecting indoor PAH emissions in real homes is the pressure in the space containing the wood stove and how it is affected by building height, the distribution of leaks in the building envelope, weather conditions and the condition and operation of other appliances (e.g., exhaust fans and forced-air systems).

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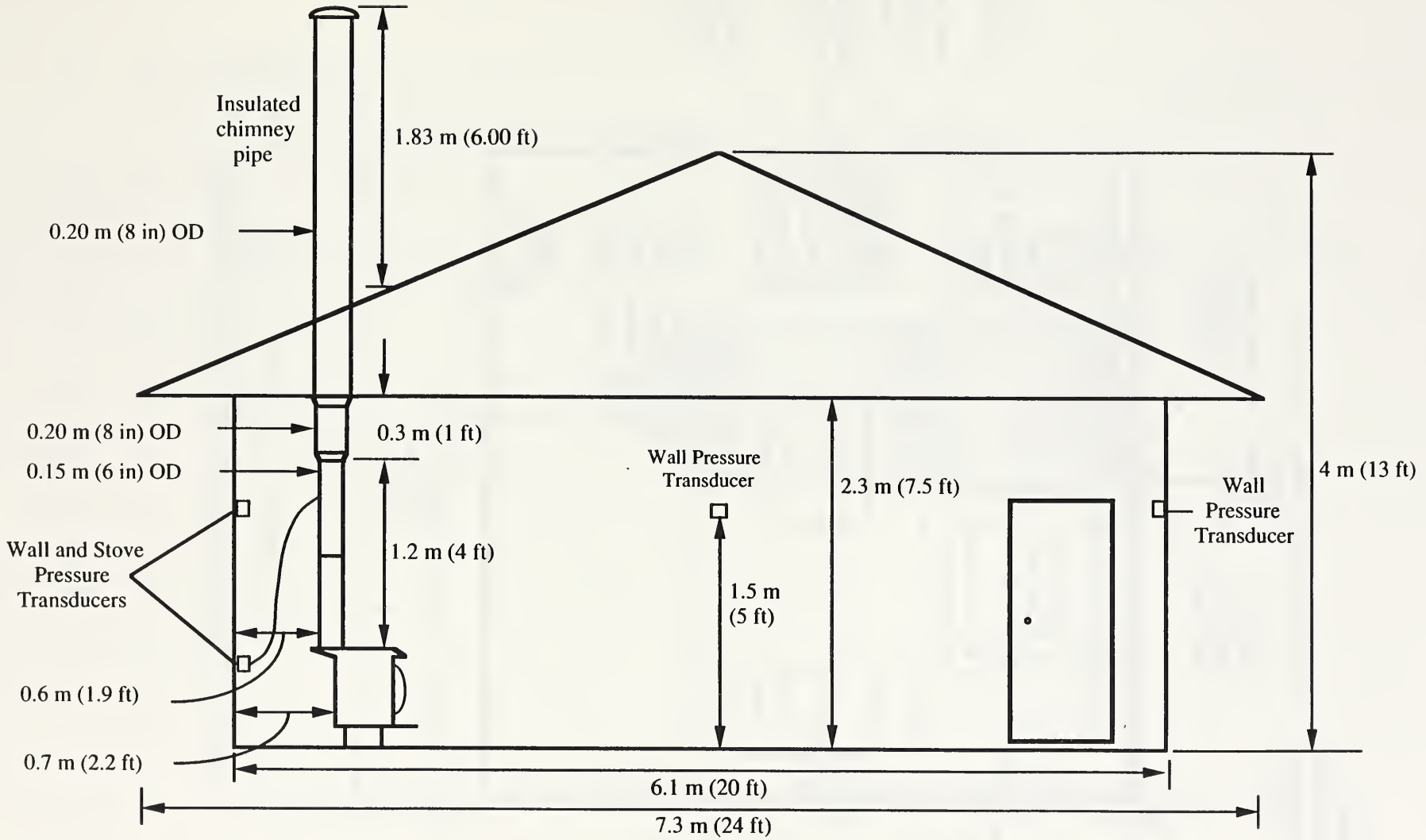
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0.20 m (8 in) OD
0.20 m (8 in) OD
0.15 m (6 in) OD
0.3 m (1 ft)
1.2 m (4 ft)
Wall and Stove Pressure Transducers
0.6 m (1.9 ft)
0.7 m (2.2 ft)
Wall Pressure Transducer
1.5 m (5 ft)
2.3 m (7.5 ft)
Wall Pressure Transducer
4 m (13 ft)
6.1 m (20 ft)
7.3 m (24 ft)

Figure 1 Schematic Elevation of Test House

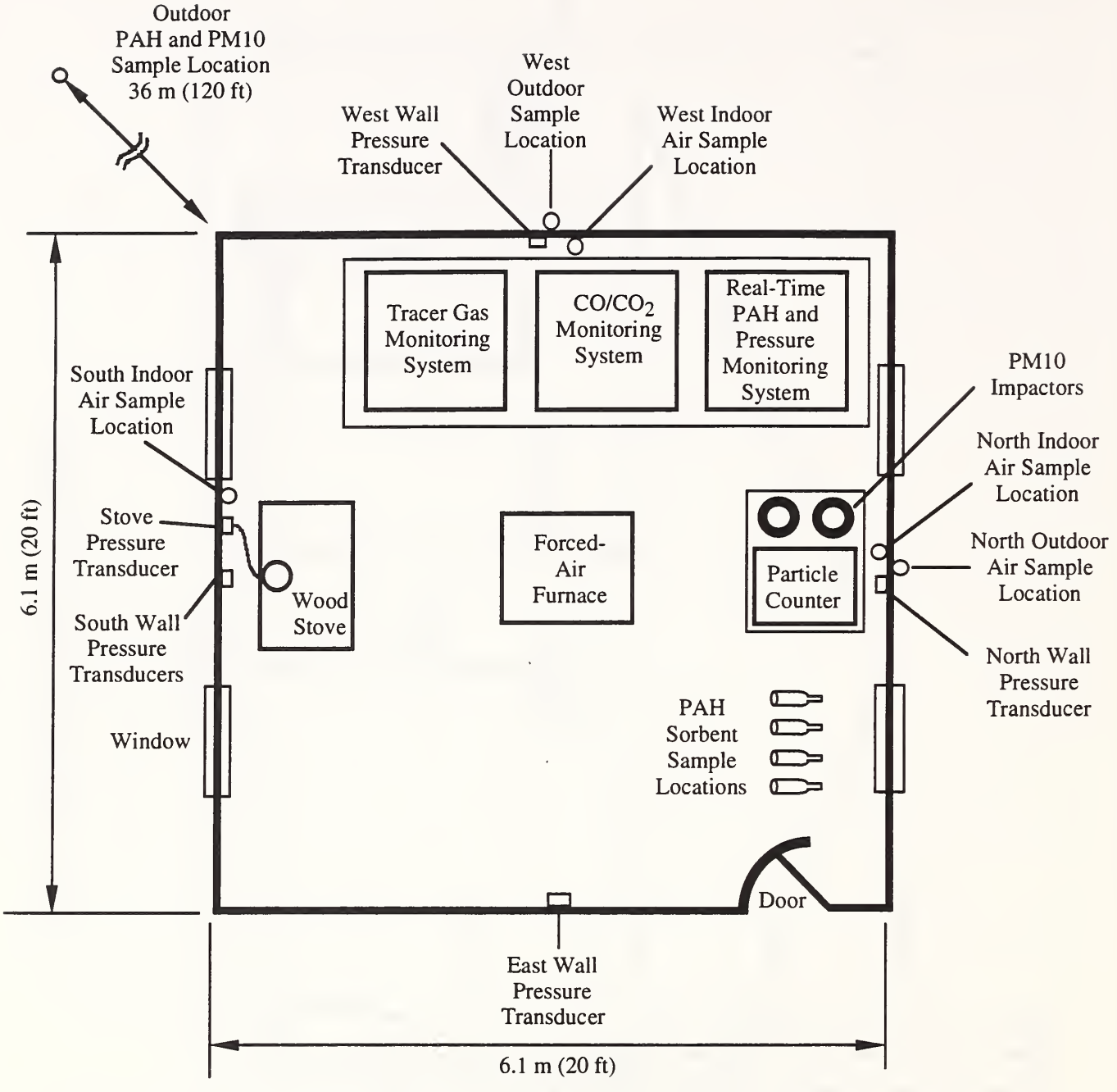

Figure 2 Floorplan Showing Location of Instrumentation

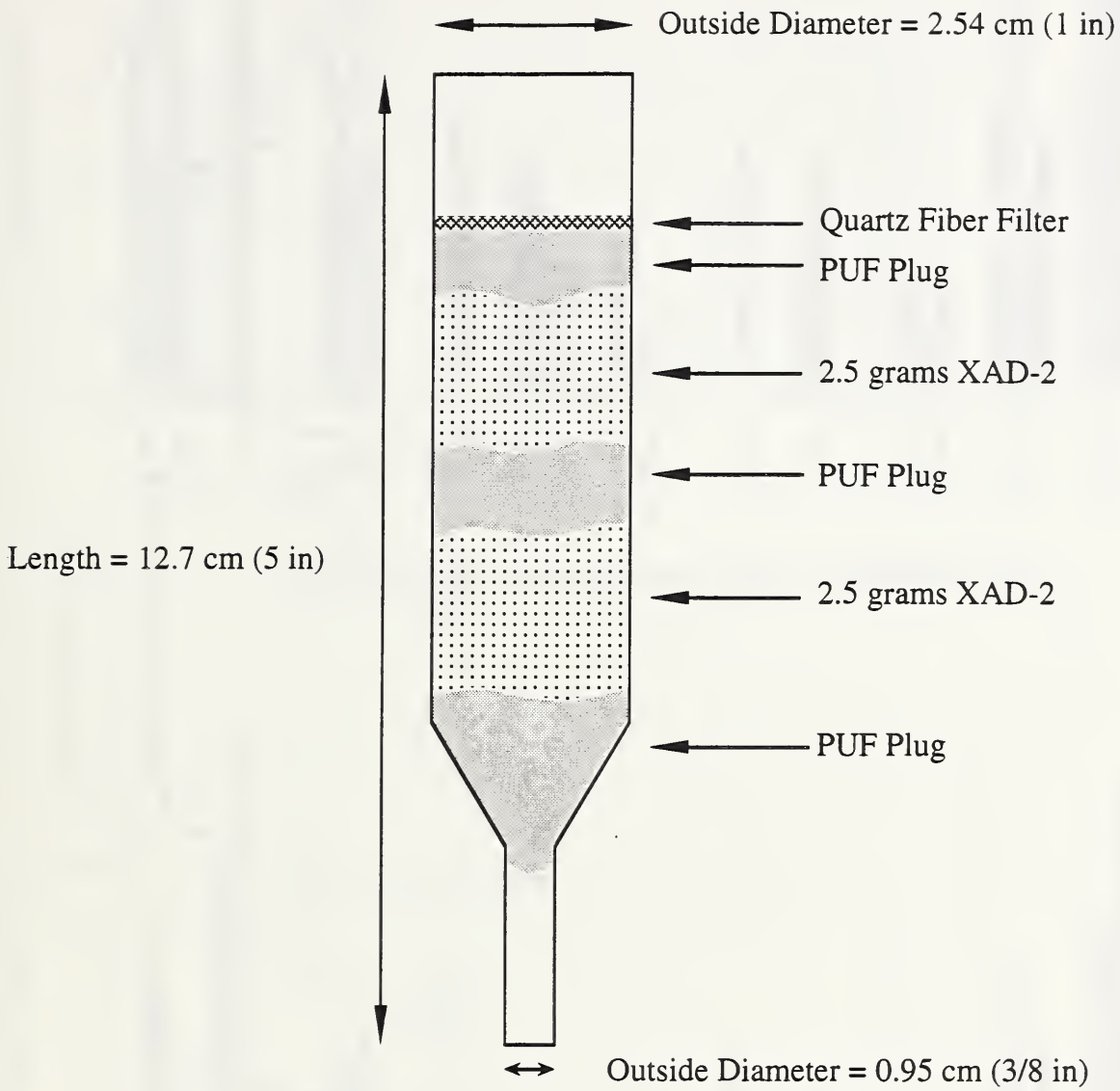

Figure 3 Schematic of Sorbent Tube

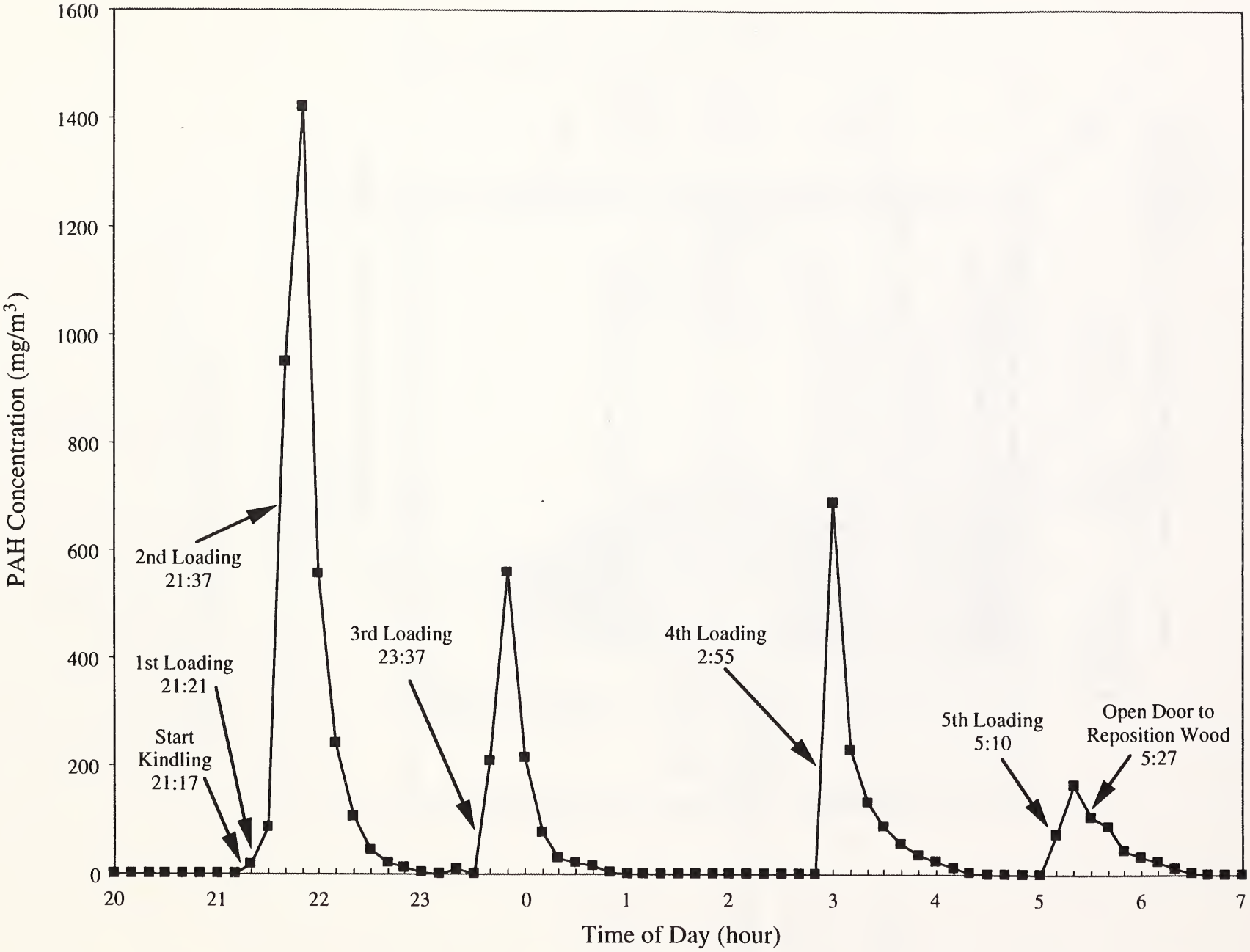

Figure 4 PAH Concentration versus time

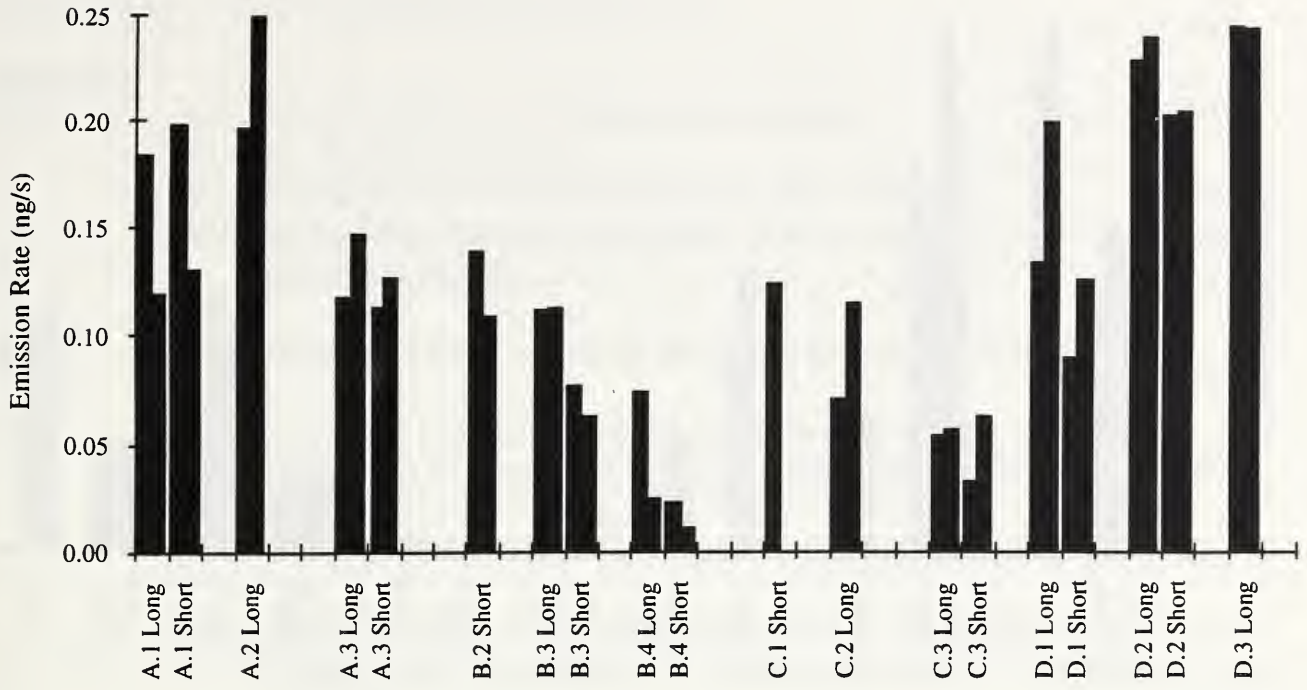

Figure 5 Total PAH Emission Rate for Individual Tests

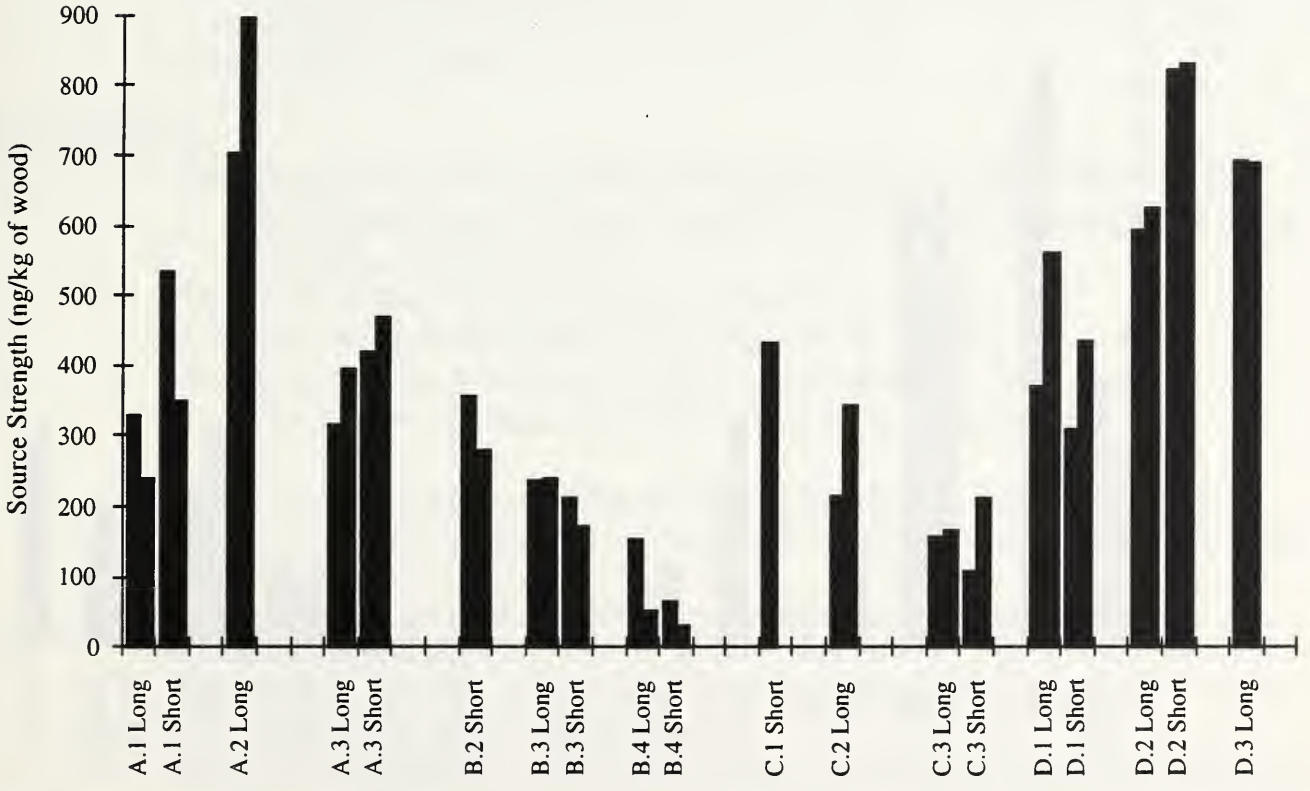

Figure 6 Total PAH Source Strength Relative to Wood Consumption for Individual Tests

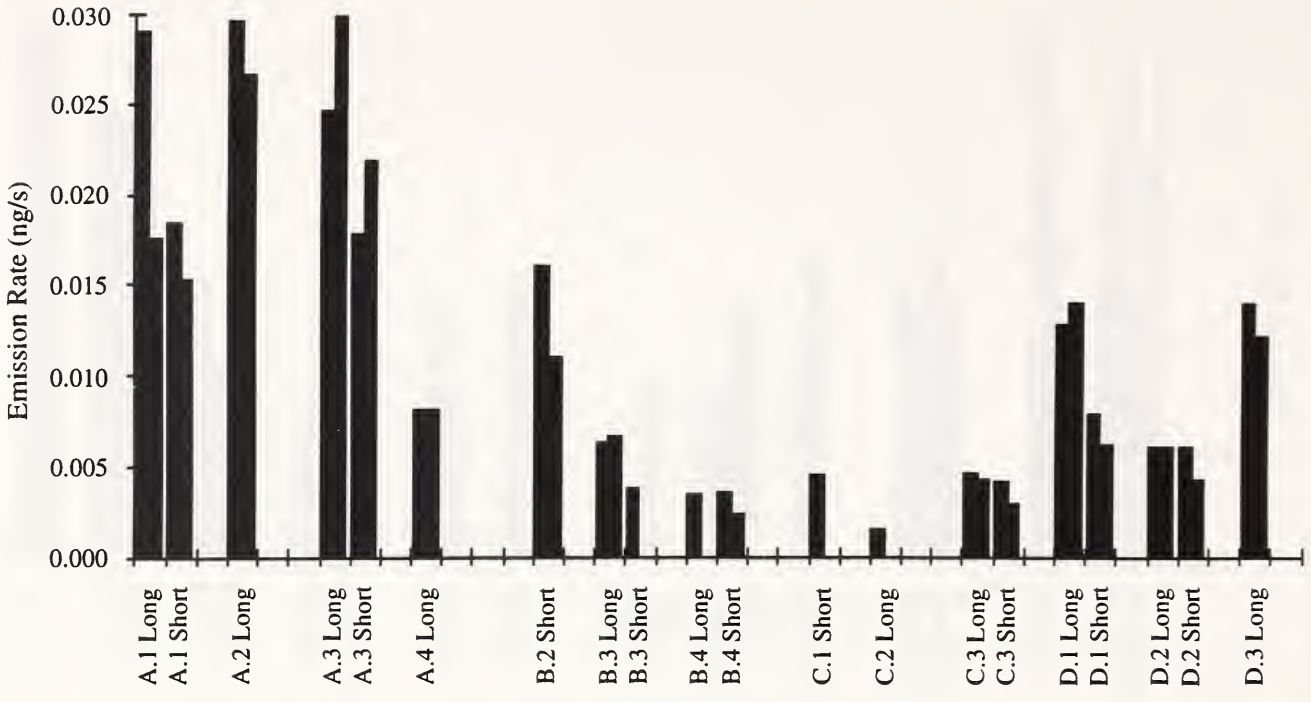

Figure 7 BaP Emission Rate for Individual Tests

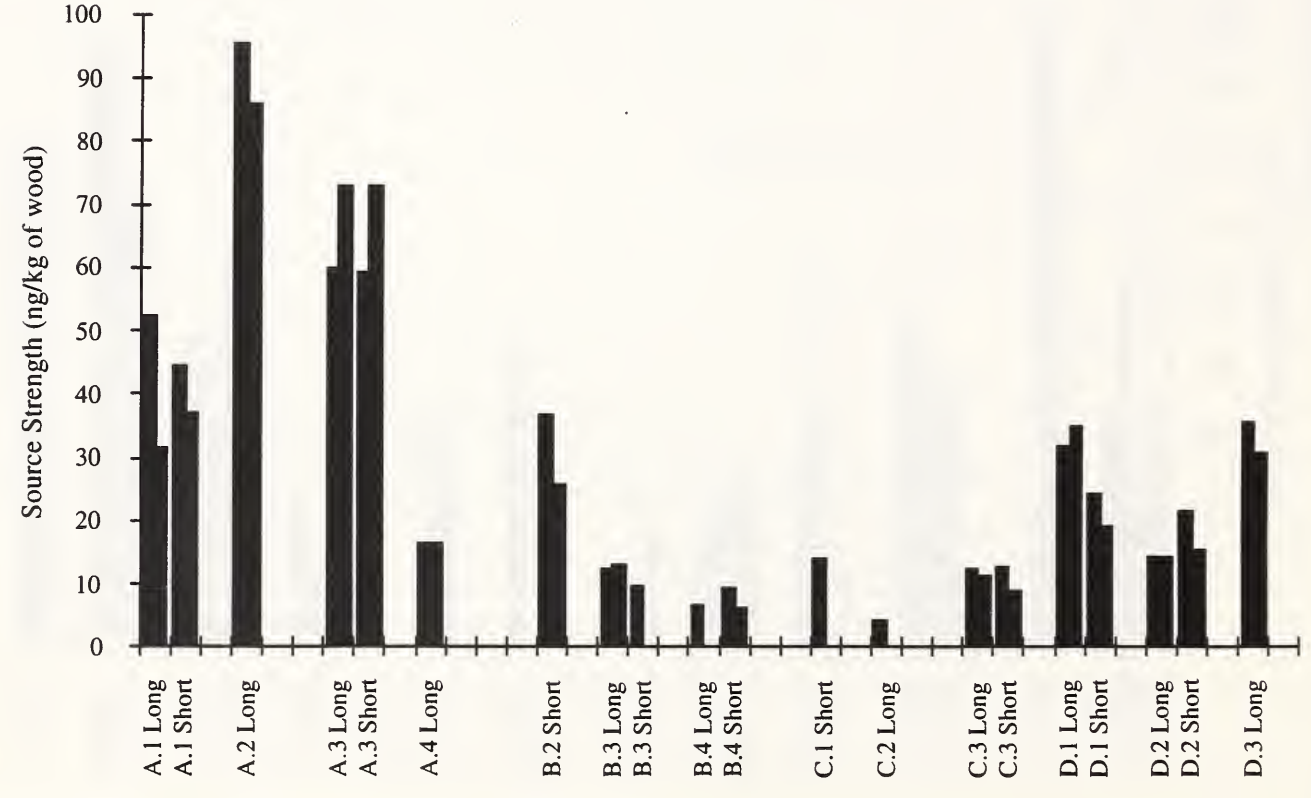

Figure 8 BaP Source Strength Relative to Wood Consumption for Individual Tests

APPENDIX A STOVE OPERATION PROTOCOL

Preparation

Wood

Day Before: Split one piece of wood for kindling.
Number 12 pieces of wood.
Weigh each piece of wood and record weight in notebook.
Measure moisture content of each piece of wood; measure in four places and record each reading.

Furnace

Set thermostat at 15 °C (about 60 °F) and set fan on continuous operation.

Stove

Open stove vent and catalytic converter (if present) all the way.
Put 3 fire starters in stove, light them and put kindling on fire.
Close door.
Record time and room temperature from the tracer gas system.

When fire is burning well: slowly open the door 1.5 cm (about 1/2 in) for 10 seconds; then slowly open the door completely, add full load of wood and close door.
Record numbers of the wood pieces, time, stove temperature and room temperature from tracer gas system.

When stove temperature reaches 200 °C (400 °F), close catalytic converter completely (if present) and partially close vent.
Record action and time.

Stove Operation

Gradually close stove vent to keep stove temperature at 200 °C (400 °F) and house temperature between 21 and 27 °C (70 and 80 °F) as displayed on the tracer gas system monitor.
Open vent when house temperature is below 21 °C (70 °F).
Close vent when house temperature is above 27 °C (80 °F).
Whenever the vent is adjusted, record the vent adjustment, time, stove temperature and room temperature from the tracer gas system.

When wood is down to one-quarter of the stove capacity: open the stove vent; slowly open the door 1.5 cm (about 1/2 in) for 10 seconds; then slowly open the door completely.
Gently rake the coals (if necessary) and reload stove to full capacity.
Close the stove door.
Record numbers of the wood pieces, time, stove temperature and room temperature from tracer gas system.
If the stove temperature drops below 150 °C (350 °F), open the catalytic converter and record action, time and stove temperature.
When stove temperature rises above 200 °C (400 °F), close the catalytic converter and record action, time and stove temperature.

When stove temperature rises above 200 °C (400 °F) or the room temperature rises above 27 °C (80 °F), gradually close the vent.
Whenever the vent is adjusted, record the vent adjustment, time, stove temperature and room temperature from the tracer gas system.

Shut Down

Stove — When test is complete, open catalytic converter and stove vent.

Furnace — Turn thermostat up to 21 °C (70 °F).

Clean Up (Day after test)

Stove — Remove ash tray and take outside house.
Empty ashes into ash bucket outside of house, leaving a bed of about 3 to 5 cm (1 or 2 in) in tray.
Replace ash tray in stove.

House — Reorganize and restock wood pile.
Sweep and wet-mop floor.

APPENDIX B INSTRUMENTATION PROTOCOL

The following protocol is organized with reference to the various data collection systems and instruments used in the tests. SF_6 refers to the automated tracer gas decay system. CO/CO_2 refers to the automated system used to monitor carbon monoxide and carbon dioxide concentrations. DAS refers to the PC-based data acquisition system used to monitor the output of the real-time PAH monitor and the pressures across the walls and in the flue. C-PC refers to the real-time particle counter. PM10 refers to the pumps and impactors to determine average particle mass over the designated sampling periods. PAH refers to the pumps and sorbent tubes used to monitor average PAH concentrations over the sampling periods.

Preparation

SF_6

Record in SF_6 notebook: P-5 cylinder pressure, base frequency, SF_6 peak time, base adjust, column temperature, detector temperature and sample flow rate.

Check airflow rate at outlets of all air sampling pumps; check back of SF_6 monitor to make sure the inlet lines are connected.

Check visually: outdoor concentrations between 0 and 1 ppb; indoor concentrations within 2 ppb of each other; values of indoor ach within 10% range. Record any deviations in SF_6 notebook.

CO/CO_2

Check visually: program is running; outdoor CO_2 concentrations are between 350 and 400 ppm and indoor concentrations within 25 ppm of each other; outdoor CO concentrations between 2 and 5 ppm and indoor concentrations within 1 ppm of each other. Record any deviations in MISC notebook.

Check back of CO_2 case to make sure inlet lines are connected.

DAS

Check visually: PAH level between 0 and 5 ng/m^3; wall pressure transducer outputs between 2.4 and 2.6 volts.

C-PC

Check visually to make sure the monitor's display is counting and that the last particle count is on PC screen.

Fill soap-film pump calibrator with soap solution.

PM10

Turn on both pumps and keep black case closed.

Connect Pump #1 tubes for indoor samples and Pump #2 tubes for outdoor samples.

Push in timer tabs for continuous operation and set time-share at 20 minutes.

Set Pump #1 at 8.50 on pot (4.58 volts) and Pump #2 at 7.90 on pot (4.40 volts).

Connect 2-conductor lines to the voltage output of both pumps for checking during test.

Select four filter cassettes: indoor long, indoor short, outdoor long, and outdoor short; record cassette numbers with sample location/duration, pump number and pump tube in PM10/PAH notebook.

PAH

Select seven PAH tubes: 2 indoor long term; 2 indoor short term; 1 outdoor long term; 1 outdoor short term; 1 field blank. Record tube numbers with sample location/duration in PM10/PAH notebook.

Set up sampling stands at indoor and outdoor sample locations, run inlet tubes from stands to pumps, and connect inlet tubes to pumps.

Connect exhaust lines to pumps and run lines outside of test house.

Place all PAH tubes at corresponding air sampling pump and turn on all 6 pumps.

Set pump airflow rates per individual pump calibration; record airflow rate setting for each pump in PM10/PAH notebook.

Long Sample Start-Up (Prior to starting stove)

PM10

Apply mineral oil to all four impactor plates and install plates and filters in impactors.

Mount outdoor/short and long impactors on outdoor bracket.

Turn off Pump #1.

Record initial elapsed time of time share box (black) and initial time from mass flow controller box (green) for Pump #1.

Connect indoor/long impactor to Pump #1 long tube, turn on Pump #1 and record time and DC voltage from pump.

Turn off Pump #2.

Record initial elapsed time of time share box (black) and initial time from mass flow controller box (green) for Pump #2.

Connect outdoor/long impactor to Pump #2 long tube, turn on Pump #2 and record time and DC voltage from pump.

PAH

Turn on and set pump airflow rates per individual pump calibration; record airflow rate setting for each pump in PM10/PAH notebook.

Connect indoor/long and outdoor/long sorbent tubes to air sampling pumps; record sorbent tube and pump numbers, location/duration (long or short) and time.

DO NOT TOUCH SORBENT TUBES OR INNER FOIL SURFACE WITH FINGERS, WEAR GLOVES

Short Sample Start-Up (After second loading of stove)

PM10

Connect indoor/short impactor to Pump #1 short tube when the pump is pulling on indoor/long impactor.

Record time, DC voltage from pump, elapsed time of time share box and time from mass flow controller for Pump #1.

Connect outdoor/short impactor to Pump #2 short tube when the pump is pulling on outdoor/long impactor.

Record time, DC voltage from pump, elapsed time of time share box and time from mass flow controller for Pump #2.

PAH

Reset pump airflow rates per individual pump calibration; record airflow rate setting for each pump in PM10/PAH notebook.

Connect indoor/short and outdoor/short sorbent tubes to air sampling pumps; record tube numbers, location/duration and time.

DO NOT TOUCH SORBENT TUBES OR INNER FOIL SURFACE WITH FINGERS, WEAR GLOVES

First Mid-Test Check (roughly 1 hour after starting short samples)

SF_6 Check and record in SF_6 notebook: base frequency, SF_6 peak time.
Check visually: outdoor concentrations between 0 and 1 ppb; indoor concentrations within 2 ppb of each other; values of indoor ach within 10% range.
Connect 10, 50, 100 and 200 ppb calibration bags to extra GC port; record time, bag concentration and GC concentration in notebook.

CO/CO_2 Check visually: outdoor concentrations between 350 and 400 ppm; indoor concentrations within 25 ppm of each other; clock is running.
Connect zero, 350 and 1029 ppm CO_2 calibration bags and 4 and 10 ppm CO calibration bags to extra outdoor port; record time, bag concentration and CO_2 or CO concentration in MISC notebook.

DAS Check visually: PAH level, not after a recent stove door opening, between 0 and 50 ng/m^3; wall pressure transducer outputs between 2.4 and 2.6 volts.

C-PC Check visually to make sure the monitor's display is counting and that the last particle count is on PC screen.

PM10 Record DC voltages for both pumps in PM10/PAH notebook.

PAH Check airflow rate on all 6 pump exhausts with soap-film calibrator; record 10 airflow rate readings, pump number and time in PM10/PAH notebook.

Second Mid-Test Check (about 4 hours after start of short samples)

SF_6 Check and record in SF_6 notebook: base frequency, SF_6 peak time.
Check visually: outdoor concentrations between 0 and 1 ppb; indoor concentrations within 2 ppb of each other; values of indoor ach within 10% range.

CO/CO_2 Check visually: outdoor concentrations between 350 and 400 ppm; indoor concentrations within 25 ppm of each other; clock is running.

DAS Check visually: PAH level, not after a recent stove door opening, between 0 and 50 ng/m^3; wall pressure transducer outputs between 2.4 and 2.6 volts.

C-PC Check visually to make sure the monitor's display is counting and that the last particle count is on PC screen.

PM10 Record DC voltages for both pumps in PM10/PAH notebook.

PAH Check airflow rate on all 6 pump exhausts with soap-film calibrator; record 10 airflow rate readings, pump number and time in PM10/PAH notebook.

Sample Shut-Down

PM10
Turn off pumps 1 and 2.
Remove cassettes from all impactors and place in plastic holders; record time in PM10/PAH notebook.
Record final elapsed time of time share box and final time from mass flow controller for pumps 1 and 2.

PAH
Turn off all Gilian pumps.
Disconnect tubes, swab off bases with methylene chloride, wrap tubes in foil and place in glass bottles; record time in PM10/PAH notebook.

DO NOT TOUCH SORBENT TUBES OR INNER FOIL SURFACE WITH FINGERS, WEAR GLOVES

Post Test

SF_6
Record in notebook: P-5 cylinder pressure, base frequency, SF_6 peak time
Check visually: outdoor concentrations between 0 and 1 ppb; indoor concentrations within 2 ppb of each other; values of indoor ach within 10% range.

CO/CO_2
Check visually: outdoor concentrations between 350 and 400 ppm; indoor concentrations within 25 ppm of each other

DAS
Check visually: PAH level between 0 and 50 ng/m^3; wall pressure transducer output is between 2.4 and 2.6 volts.

C-PC
Check visually to make sure the monitor's display is counting and that the last particle count is on PC screen.

PM10
Unmount outdoor impactors and take inside.
Disassemble impactors and take impactor plates back to lab for cleaning.
Take cassettes back to lab for storage prior to shipment for analysis.

PAH
Take outdoor sampling stands inside.
Take sorbent tubes back to lab for storage in refrigerator.

Non-Test Day

SF_6
Check load time and peak separation; calibrate GC.

CO/CO_2
Calibrate.

DAS
Check zero of pressure gauges.

PM10
Calibrate both pumps and all four impactors at 10 L/min.

APPENDIX C TEST SUMMARY TABLES

The following are the stove test summary tables previously described in the section on Test Results (page 12). This appendix includes a summary sheet on all acceptable stove tests. Each summary sheet contains the stove test ID number in the caption at the top.

Summary of Results of Stove Test A.1

HOURLY AVERAGE DATA

Hour	Tin (°C)	Tout (°C)	Wind Speed (m/s)	In - Out CO (ppm)	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	Particle Count Concentration Number of Particles/m^3 .3-.5	.5-.7	.7-1.0	1-5	5-10	>10	Pressure Flue (Pa)	Pressure Wall (Pa)	Total PAH EcoChem (ng/m^3)	ACH (h^{-1})
0600	---	---	---	0.2	442	402	---	---	---	---	---	---	---	---	---	---
0700	---	---	---	0.0	651	408	---	---	---	---	---	---	---	---	---	---
0800	---	---	---	0.1	1133	424	1.48E+07	8.68E+06	4.66E+06	1.94E+06	1.80E+04	8.78E+03	0.17	0.20	129	---
0900	21.9	---	0.6	0.0	1282	396	1.39E+07	7.01E+06	3.43E+06	1.28E+06	5.77E+03	2.58E+03	-17.58	-0.23	308	---
1000	23.9	---	2.3	0.0	912	380	9.42E+06	1.06E+01	2.29E+06	8.93E+05	5.16E+03	2.46E+03	-27.28	-1.18	67	0.51
1100	25.2	---	1.1	0.0	880	379	6.93E+06	2.95E+06	1.38E+06	5.08E+05	2.56E+03	1.20E+03	-16.08	-0.47	6	---
1200	26.8	---	0.5	1.8	1027	380	9.49E+06	3.51E+06	1.72E+06	7.01E+05	4.92E+03	2.32E+03	-15.05	-0.46	168	0.42
1300	28.2	---	0.4	1.5	1102	378	8.38E+06	2.27E+06	1.07E+06	4.15E+05	3.05E+03	1.52E+03	-12.95	-0.71	91	---
1400	---	---	---	1.1	1447	393	9.98E+06	5.34E+06	2.96E+06	1.32E+06	1.28E+04	6.60E+03	-14.48	-0.48	35	---
1500	28.1	---	0.3	2.2	1628	414	1.88E+07	5.71E+06	2.41E+06	9.18E+05	6.81E+03	3.22E+03	-12.90	-0.50	269	0.35
1600	27.3	2.0	0.3	2.3	1728	400	1.34E+07	4.06E+06	1.76E+06	6.44E+05	5.12E+03	2.52E+03	-8.81	-0.77	71	---
1700	26.9	2.1	0.4	2.1	1482	358	1.01E+07	3.28E+06	1.45E+06	5.55E+05	5.72E+03	2.94E+03	-9.43	-0.66	24	---
1800	26.5	2.1	0.4	2.3	1422	351	9.33E+06	3.97E+06	1.87E+06	7.27E+05	6.19E+03	3.01E+03	-7.00	-0.80	7	0.32
1900	24.3	2.2	0.7	---	---	---	4.91E+06	1.44E+06	5.04E+05	1.36E+05	5.10E+02	2.34E+02	-5.15	-0.80	---	---
2000	22.9	2.4	0.9	---	---	---	4.09E+06	7.50E+05	2.21E+05	6.51E+04	5.48E+02	2.83E+02	-5.29	-0.72	---	---

FUEL CONSUMPTION

EVENT	TIME	LOAD (kg)
Start of fire	0830	2.24
First Loading	0845	4.65
Second Loading	0920	5.28
Third Loading	1200	3.70
Fourth Loading	1505	6.55

SAMPLING TIMES	
Start of long samples	0809-0829
Start of short samples	1039-1044
End of long and short samples	1706-1730

PM10 RESULTS ($\mu g/m^3$)

SAMPLE	CONCENTRATION	UNCERTAINTY
In-long	92	21
In-short	77	20
Out-long	4	4
Out-short	4	5

Summary of Results of Stove Test A.2

HOURLY AVERAGE DATA

Hour	Tin (°C)	Tout (°C)	Wind Speed (m/s)	In - Out CO (ppm)	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	Particle Count Concentration Number of Particles/m^3 .3-.5	.5-.7	.7-1.0	1-5	5-10	>10	Pressure Flue (Pa)	Pressure Wall (Pa)	Total PAH EcoChem (ng/m^3)	ACH (h^{-1})
0600	13.7	-0.5	0.3	---	---	---	2.06E+06	2.67E+05	1.03E+05	3.97E+04	2.95E+02	1.45E+02	-0.25	-0.09	---	---
0700	13.7	-0.8	0.3	---	---	---	2.99E+06	1.15E+06	6.73E+05	3.36E+05	8.20E+03	3.79E+03	0.23	-0.08	1.5	0.28
0800	13.7	1.3	0.3	0.1	1102	392	1.82E+07	1.28E+07	7.75E+06	3.70E+06	8.95E+04	3.94E+04	0.01	0.16	17.5	---
0900	---	---	---	0.3	1127	382	1.80E+07	8.12E+06	4.13E+06	1.73E+06	2.33E+04	9.34E+03	-10.83	0.48	516	---
1000	25.2	4.3	0.5	0.9	1138	374	2.06E+07	7.84E+06	3.73E+06	1.50E+06	9.20E+03	3.83E+03	-11.63	-0.06	370	0.29
1100	27.2	5.5	0.6	1.7	1177	369	1.93E+07	7.68E+06	3.84E+06	1.62E+06	1.12E+04	4.90E+03	-9.69	-0.28	65	---
1200	29.0	6.4	0.4	2.4	1239	365	1.67E+07	6.61E+06	3.09E+06	1.16E+06	6.15E+03	2.76E+03	-7.18	-0.35	38	0.28
1300	30.1	7.4	0.6	2.4	1154	359	1.34E+07	4.81E+06	2.20E+06	8.30E+05	5.73E+03	2.53E+03	-9.75	-0.45	59	---
1400	31.1	7.9	0.4	2.4	928	356	1.07E+07	2.53E+06	9.29E+05	2.68E+05	6.58E+02	2.51E+02	-7.95	-0.52	12	---
1500	---	---	---	2.3	1043	355	1.33E+07	3.99E+06	1.85E+06	7.72E+05	7.21E+03	3.55E+03	-7.78	-0.74	43	---
1600	---	---	---	2.6	1212	356	2.25E+07	7.30E+06	3.37E+06	1.44E+06	9.89E+03	4.73E+03	-7.87	-0.80	76	---
1700	0.0	5.3	0.7	1.9	1192	361	2.05E+07	5.15E+06	2.11E+06	8.77E+05	5.75E+03	2.70E+03	-12.07	-0.70	64	---
1800	---	---	---	1.6	1166	---	1.90E+07	5.33E+06	2.58E+06	1.11E+06	5.84E+03	2.78E+03	-13.72	-0.80	22	---
1900	---	---	---	1.2	906	---	1.95E+07	2.00E+07	1.41E+07	7.85E+06	4.26E+04	1.80E+04	-17.42	-0.46	79	---
2000	---	---	---	---	---	---	1.06E+07	4.35E+06	2.14E+06	7.41E+05	6.92E+02	2.26E+02	-16.63	-0.27	---	---
2100	---	---	---	---	---	---	7.04E+06	1.43E+06	4.74E+05	1.13E+05	2.41E+02	8.77E+01	-12.38	-0.19	---	---
2200	---	---	---	---	---	---	6.01E+06	7.80E+05	1.84E+05	3.58E+04	1.02E+02	3.99E+01	-9.71	-0.14	---	---

FUEL CONSUMPTION

EVENT	TIME	LOAD (kg)
Start of fire	0908	2.25
First Loading	0922	6.16
Second Loading	1254	4.41
Third Loading	1532	1.68
Fourth Loading	1635	2.05

SAMPLING TIMES	
Start of long samples	0859-0905
Start of short samples	1055-1112
End of long and short samples	1801-1845

PM10 RESULTS ($\mu g/m^3$)

SAMPLE	CONCENTRATION	UNCERTAINTY
In-long	86	20
In-short	66	17
Out-long	10	4
Out-short	9	6

Summary of Results of Stove Test A.3

HOURLY AVERAGE DATA

Hour	Tin (°C)	Tout (°C)	Wind Speed (m/s)	In - Out CO (ppm)	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	Particle Count Concentration Number of Particles/m^3 .3-.5	.5-.7	.7-1.0	1-5	5-10	>10	Pressure Flue (Pa)	Pressure Wall (Pa)	Total PAH EcoChem (ng/m^3)	ACH (h^{-1})
0600	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
0700	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
0800	14.2	-3.9	0.6	---	1260	398	---	---	---	---	---	---	---	---	---	---
0900	17.8	-2.2	0.7	---	1235	388	1.87E+07	6.38E+06	2.73E+06	1.06E+06	1.24E+04	4.78E+03	-11.95	-0.15	605	0.49
1000	25.4	-0.9	0.7	0.9	1079	381	1.21E+07	3.56E+06	1.50E+06	5.72E+05	5.66E+03	2.51E+03	-12.32	-1.63	356	---
1100	---	---	---	0.9	1371	377	1.65E+07	8.33E+06	4.26E+06	1.77E+06	1.21E+04	6.01E+03	-10.90	-2.30	24	---
1200	---	---	---	1.3	1551	372	1.41E+07	6.18E+06	2.80E+06	1.01E+06	7.49E+03	4.04E+03	-7.49	-2.85	3	---
1300	---	---	---	2.1	1642	363	2.70E+07	7.82E+06	2.64E+06	1.03E+06	9.72E+03	5.05E+03	-7.67	-3.03	2725	---
1400	30.5	2.8	0.8	2.4	1658	357	2.21E+07	7.37E+06	3.49E+06	1.51E+06	1.41E+04	6.97E+03	-6.97	-3.02	1043	---
1500	29.9	2.1	0.6	2.3	1479	353	1.78E+07	4.99E+06	2.17E+06	7.95E+05	3.93E+03	1.84E+03	-3.25	-3.23	190	---
1600	---	---	---	1.9	1402	354	1.40E+07	4.94E+06	2.51E+06	1.09E+06	8.73E+03	4.71E+03	-7.85	-2.95	39	---
1700	---	---	---	1.6	1517	354	1.28E+07	4.74E+06	2.34E+06	9.88E+05	1.11E+04	6.04E+03	-6.03	-3.01	12	---
1800	---	---	---	4.1	1212	---	1.09E+07	4.79E+06	2.55E+06	1.14E+06	7.18E+03	3.74E+03	-11.46	-2.10	72	---
1900	---	---	---	3.9	870	---	6.93E+06	1.95E+06	7.76E+05	2.50E+05	3.97E+02	1.51E+02	-9.88	-1.78	12	---
2000	---	---	---	---	---	---	5.21E+06	8.69E+05	2.18E+05	4.71E+04	1.34E+02	5.69E+01	-6.63	-1.55	15	---

FUEL CONSUMPTION

EVENT	TIME	LOAD (kg)
Start of fire	0855	2.25
First Loading	0905	4.16
Second Loading	1023	6.74
Third Loading	1316	1.51
Fourth Loading	1554	3.01

SAMPLING TIMES	
Start of long samples	0842-0851
Start of short samples	1031-1255
End of long and short samples	1732-1804

PM10 RESULTS ($\mu g/m^3$)

SAMPLE	CONCENTRATION	UNCERTAINTY
In-long	94	22
In-short	73	21
Out-long	-7	4
Out-short	-2	7

Summary of Results of Stove Test A.4

HOURLY AVERAGE DATA

Hour	Tin (°C)	Tout (°C)	Wind Speed (m/s)	In - Out CO (ppm)	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	Particle Count Concentration Number of Particles/m^3 .3-.5	.5-.7	.7-1.0	1-5	5-10	>10	Pressure Flue (Pa)	Pressure Wall (Pa)	Total PAH EcoChem (ng/m^3)	ACH (h^{-1})
0600	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
0700	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
0800	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
0900	17.5	-1.8	1.2	0.0	800	390	9.08E+06	2.21E+06	1.03E+06	4.78E+05	1.02E+04	4.81E+03	---	---	67	---
1000	20.0	-1.4	1.2	0.6	975	386	1.11E+07	2.06E+06	7.71E+05	3.01E+05	4.78E+03	2.24E+03	---	---	142	0.26
1100	20.7	-1.1	1.3	1.0	1126	381	9.62E+06	2.07E+06	8.66E+05	3.59E+05	6.45E+03	3.02E+03	---	---	84	---
1200	22.1	-0.9	1.1	1.1	1099	368	9.45E+06	2.57E+06	1.23E+06	5.25E+05	5.00E+03	2.43E+03	---	---	598	0.14
1300	22.0	-0.5	1.2	1.5	1189	361	5.98E+06	1.60E+06	7.13E+05	2.81E+05	4.62E+03	2.23E+03	---	---	40	---
1400	23.1	0.0	1.4	1.6	1278	361	7.05E+06	1.73E+06	7.56E+05	3.14E+05	5.31E+03	2.55E+03	-17.12	0.19	156	0.13
1500	23.6	0.2	1.4	1.4	1218	355	5.48E+06	1.59E+06	7.65E+05	3.32E+05	4.15E+03	2.06E+03	-17.19	0.05	73	---
1600	24.8	0.2	1.6	1.4	1051	351	4.33E+06	1.32E+06	6.24E+05	2.52E+05	3.56E+03	1.70E+03	-22.55	0.21	142	---
1700	---	---	---	1.5	1033	350	4.06E+06	1.52E+06	7.06E+05	2.81E+05	3.62E+03	1.72E+03	---	---	---	---
1800	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1900	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
2000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

FUEL CONSUMPTION

EVENT	TIME	LOAD (kg)
Start of fire	0914	2.18
First Loading	0927	3.62
Second Loading	0952	3.41
Third Loading	1150	1.41
Fourth Loading	1421	5.24
Fifth Loading	1548	0.87

SAMPLING TIMES	
Start of long samples	0840-0907
Start of short samples	1027-1039
End of long and short samples	1720-1725

PM10 RESULTS ($\mu g/m^3$)

SAMPLE	CONCENTRATION	UNCERTAINTY
In-long	26	7
In-short	29	9
Out-long	1	4
Out-short	-3	5

Summary of Results of Stove Test B.2

HOURLY AVERAGE DATA

Hour	Tin (°C)	Tout (°C)	Wind Speed (m/s)	In - Out CO (ppm)	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	Particle Count Concentration Number of Particles/m^3 .3-.5	.5-.7	.7-1.0	1-5	5-10	>10	Pressure Flue (Pa)	Pressure Wall (Pa)	Total PAH EcoChem (ng/m^3)	ACH (h^{-1})
1800	16.2	-1.2	1.1	---	---	---	4.50E+06	1.06E+06	2.75E+05	5.30E+04	3.59E+02	1.71E+02	0.26	0.04	---	---
1900	14.9	-1.9	1.1	0.1	441	368	3.12E+06	3.52E+05	6.77E+04	1.79E+04	2.83E+02	1.32E+02	0.44	0.00	0	---
2000	13.9	-2.8	1.0	0.0	498	369	3.70E+06	7.47E+05	3.40E+05	1.61E+05	5.71E+03	2.79E+03	-0.70	-0.03	14	0.32
2100	17.0	-3.2	1.1	0.4	651	369	2.78E+07	5.13E+06	6.79E+05	2.26E+05	6.98E+03	3.35E+03	-17.76	-0.41	437	---
2200	21.7	-3.7	1.0	0.9	671	369	1.97E+07	2.35E+06	4.57E+05	1.88E+05	5.12E+03	2.59E+03	-18.52	-0.95	123	---
2300	26.2	-3.8	1.2	0.9	713	367	1.05E+07	2.76E+06	1.43E+06	6.62E+05	1.73E+04	8.60E+03	-19.10	-1.06	33	0.30
0000	25.5	-4.5	1.0	0.8	910	365	7.88E+06	2.60E+06	1.29E+06	5.72E+05	1.38E+04	7.03E+03	-16.43	-1.16	1	---
0100	25.9	-5.0	1.3	0.7	1006	362	8.07E+06	3.36E+06	1.74E+06	7.70E+05	1.66E+04	8.24E+03	-18.50	-0.74	0	---
0200	25.3	-5.4	1.3	0.6	942	358	9.09E+06	2.31E+06	7.72E+05	2.84E+05	6.63E+03	3.39E+03	-18.25	-0.78	5	0.30
0300	28.0	-5.7	1.3	0.9	837	355	1.27E+07	2.12E+06	3.12E+05	9.80E+04	1.46E+03	7.07E+02	-21.46	-0.90	156	---
0400	27.5	-5.9	1.3	0.9	795	355	5.43E+06	9.24E+05	3.23E+05	1.31E+05	3.30E+03	1.73E+03	-15.91	-1.10	53	0.30
0500	25.8	-6.1	1.2	1.1	890	354	1.69E+07	5.57E+06	1.38E+06	5.17E+05	1.30E+04	6.36E+03	-18.37	-1.02	25	---
0600	28.7	-6.1	1.1	2.0	804	353	9.23E+06	1.81E+06	4.98E+05	1.75E+05	2.83E+03	1.45E+03	-17.44	-1.41	75	---
0700	25.2	-5.1	1.2	1.5	733	354	1.11E+07	4.68E+06	1.98E+06	7.04E+05	1.01E+04	4.94E+03	-13.51	-0.98	31	0.37
0800	24.1	-3.6	1.5	1.2	599	353	5.27E+06	1.12E+06	2.64E+05	5.76E+04	8.12E+02	3.99E+02	-14.51	-0.72	3	---
0900	24.5	-1.7	1.4	1.0	517	354	3.10E+06	3.71E+05	7.64E+04	2.56E+04	4.82E+02	2.17E+02	-11.90	-0.77	---	0.38

FUEL CONSUMPTION

EVENT	TIME	LOAD (kg)
Start of fire	2052	2.31
First Loading	2059	3.27
Second Loading	2120	4.35
Third Loading	2239	4.74
Fourth Loading	0032	3.57
Fifth Loading	0231	6.55
Sixth Loading	0513	4.71
Seventh Loading	0550	1.61

SAMPLING TIMES	
Start of long samples	2016-2039
Start of short samples	2230-2248
End of long and short samples	0649-0710

PM10 RESULTS ($\mu g/m^3$)

SAMPLE	CONCENTRATION	UNCERTAINTY
In-long	37	9
In-short	37	11
Out-long	5	3
Out-short	6	3

Summary of Results of Stove Test B.3

HOURLY AVERAGE DATA

Hour	Tin (°C)	Tout (°C)	Wind Speed (m/s)	In - Out CO (ppm)	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	Particle Count Concentration Number of Particles/m^3 .3-.5	.5-.7	.7-1.0	1-5	5-10	>10	Pressure Flue (Pa)	Pressure Wall (Pa)	Total PAH EcoChem (ng/m^3)	ACH (h^{-1})
1800	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1900	---	---	---	---	---	---	9.34E+09	5.08E+06	2.66E+06	1.14E+06	1.96E+04	9.42E+03	---	---	---	---
2000	---	---	---	---	---	---	9.39E+06	5.08E+06	2.66E+06	1.14E+06	1.96E+04	9.24E+03	---	---	4	---
2100	17.9	-0.8	0.4	-0.1	706	382	1.78E+07	7.41E+06	2.76E+06	9.01E+05	6.62E+03	3.27E+03	-10.49	0.12	38	---
2200	21.0	-1.1	0.3	0.2	633	390	1.70E+07	4.44E+06	8.43E+05	1.73E+05	8.95E+02	4.23E+02	-15.37	-0.18	53	0.52
2300	24.9	-0.5	0.3	0.2	785	404	1.28E+07	3.79E+06	1.39E+06	5.94E+05	8.99E+03	4.49E+03	-13.85	-0.29	45	---
0000	26.2	-0.4	0.2	0.3	1092	397	1.20E+07	4.63E+06	2.27E+06	1.06E+06	1.57E+04	7.95E+03	-13.27	-0.47	25	---
0100	28.1	0.0	0.2	0.5	1171	389	1.03E+07	3.57E+06	1.64E+06	6.64E+05	6.38E+03	3.25E+03	-14.21	-0.48	6	---
0200	28.5	0.1	0.3	0.5	1023	392	1.02E+07	2.98E+06	1.25E+06	4.69E+05	3.88E+03	1.96E+03	-15.02	-0.40	21	0.59
0300	29.2	0.3	0.4	0.9	898	359	8.06E+06	2.19E+06	9.52E+05	4.29E+05	8.02E+03	3.55E+03	-13.20	-0.37	9	---
0400	30.3	-0.8	0.2	1.3	1000	352	1.19E+07	5.40E+06	2.98E+06	1.47E+06	1.61E+04	7.67E+03	-16.77	-0.72	2	---
0500	30.9	-1.0	0.3	1.7	1084	353	8.99E+06	3.24E+06	1.57E+06	6.61E+05	8.88E+03	4.08E+03	-14.14	-0.69	16	0.54
0600	30.7	-0.9	0.7	2.1	928	354	8.95E+06	2.16E+06	7.75E+05	2.77E+05	1.63E+03	6.66E+02	-13.92	-0.97	24	---
0700	29.3	-0.7	1.1	1.2	780	359	8.41E+06	3.15E+06	1.66E+06	7.66E+05	2.85E+03	1.24E+03	-17.33	-1.10	32	0.81
0800	29.3	-0.2	1.3	0.7	591	361	6.54E+06	9.75E+05	2.96E+05	9.01E+04	5.47E+02	2.52E+02	-15.99	-0.77	50	---
0900	24.5	0.3	1.1	0.3	495	366	5.60E+06	5.36E+05	1.35E+05	5.25E+04	9.01E+02	4.25E+02	-9.42	-0.61	92	0.57
1000	21.7	0.7	0.9	---	---	---	4.68E+06	4.05E+05	7.71E+04	2.48E+04	4.15E+02	1.96E+02	-6.19	-0.37	---	---

FUEL CONSUMPTION

EVENTS	TIME	LOAD (kg)
Start of fire	2101	2.26
First Loading	2105	4.06
Second Loading	2123	2.89
Third Loading	2306	2.78
Fourth Loading	0059	4.08
Fifth Loading	0202	1.10
Sixth Loading	0356	5.65
Seventh Loading	0546	2.83

SAMPLING TIMES	
Start of long samples	2038-2056
Start of short samples	2252-2328
End of long and short samples	0704-0716

PM10 RESULTS ($\mu g/m^3$)

SAMPLE	CONCENTRATION	UNCERTAINTY
In-long	49	11
In-short	46	12
Out-long	7	4
Out-short	11	5

Summary of Results of Stove Test B.4

HOURLY AVERAGE DATA

Hour	Tin (°C)	Tout (°C)	Wind Speed (m/s)	In - Out CO (ppm)	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	Particle Count Concentration Number of Particles/m^3 .3-.5	.5-.7	.7-1.0	1-5	5-10	>10	Pressure Flue (Pa)	Pressure Wall (Pa)	Total PAH EcoChem (ng/m^3)	ACH (h^{-1})
1800	---	---	---	-0.1	586	388	4.20E+06	1.71E+06	7.85E+05	3.17E+05	3.79E+03	1.87E+03	2.51	-0.14	---	---
1900	21.0	9.2	0.2	0.0	544	386	2.46E+06	6.01E+05	1.79E+05	4.12E+04	1.47E+02	7.71E+01	2.63	-0.14	0	0.29
2000	19.9	8.0	0.2	0.0	544	385	2.52E+06	8.53E+05	4.35E+05	2.15E+05	7.83E+03	3.90E+03	2.61	-0.12	0	---
2100	20.7	6.9	0.3	-0.3	684	406	5.55E+06	1.75E+06	7.73E+05	3.26E+05	5.77E+03	2.90E+03	-9.12	-0.04	23	---
2200	24.0	5.9	0.2	0.2	680	407	1.16E+07	3.41E+06	7.45E+05	1.49E+05	9.46E+02	4.41E+02	-8.48	-0.36	18	0.33
2300	25.7	5.6	0.3	0.3	657	404	9.76E+06	2.97E+06	9.38E+05	3.62E+05	7.31E+03	3.54E+03	-8.49	-0.47	17	---
0000	26.1	4.0	0.2	0.6	944	401	1.22E+07	6.23E+06	3.06E+06	1.23E+06	1.09E+04	5.30E+03	-8.51	-0.56	12	---
0100	26.5	3.3	0.2	0.6	1106	400	1.01E+07	3.97E+06	1.45E+06	4.77E+05	3.62E+03	1.80E+03	-9.39	-0.47	7	0.44
0200	26.4	2.5	0.3	0.5	1237	415	1.59E+07	4.43E+06	9.04E+05	2.80E+05	3.58E+03	1.79E+03	-9.46	-0.62	45	---
0300	27.3	2.4	0.2	0.3	1291	408	1.02E+07	2.41E+06	8.25E+05	3.41E+05	4.76E+03	2.44E+03	-12.15	-0.52	24	0.44
0400	29.5	3.0	0.3	0.6	1083	401	9.59E+06	1.89E+06	4.63E+05	1.51E+05	5.92E+02	2.68E+02	-12.06	-0.68	25	---
0500	28.8	2.6	0.2	1.3	928	374	7.33E+06	1.25E+06	3.30E+05	1.07E+05	1.98E+03	1.01E+03	-8.53	-0.67	17	0.42
0600	28.0	2.9	0.2	1.7	929	378	6.84E+06	1.24E+06	3.75E+05	1.29E+05	1.46E+03	7.56E+02	-10.65	-0.68	16	---
0700	28.8	4.8	0.2	0.7	900	394	6.10E+06	1.02E+06	3.12E+05	1.06E+05	1.23E+03	6.59E+02	-9.78	-0.62	60	0.34
0800	30.0	10.5	0.3	1.1	785	375	4.22E+06	6.21E+05	1.73E+05	6.04E+04	1.02E+03	5.15E+02	-5.64	-0.41	81	---
0900	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

FUEL CONSUMPTION

EVENT	TIME	LOAD (kg)
Start of fire	2102	2.31
First Loading	2108	5.06
Second Loading	2140	2.17
Third Loading	0113	5.26
Fourth Loading	0333	4.04
Fifth Loading	0551	3.41

SAMPLING TIMES	
Start of long samples	2044-2055
Start of short samples	2148-2153
End of long and short samples	0701-0718

PM10 RESULTS ($\mu g/m^3$)

SAMPLE	CONCENTRATION	UNCERTAINTY
In-long	18	5
In-short	23	7
Out-long	15	5
Out-short	20	6

Summary of Results of Stove Test C.1

HOURLY AVERAGE DATA

Hour	Tin (°C)	Tout (°C)	Wind Speed (m/s)	In - Out CO (ppm)	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	Particle Count Concentration Number of Particles/m^3 .3-.5	.5-.7	.7-1.0	1-5	5-10	>10	Pressure Flue (Pa)	Pressure Wall (Pa)	Total PAH EcoChem (ng/m^3)	ACH (h^{-1})
1800	21.9	6.8	0.4	---	---	---	8.00E+06	5.98E+05	1.05E+05	2.66E+04	1.03E+02	4.77E+01	-0.05	-0.02	---	---
1900	20.8	5.8	0.2	0.0	442	393	6.89E+06	4.72E+05	9.17E+04	2.41E+04	4.72E+01	2.19E+01	0.09	0.00	---	0.29
2000	20.0	4.5	0.3	0.0	442	400	6.17E+06	4.99E+05	1.52E+05	6.12E+04	2.02E+03	9.48E+02	-0.03	0.01	0	---
2100	19.6	4.6	0.4	0.2	598	390	1.03E+07	2.11E+06	9.32E+05	4.38E+05	1.15E+04	5.66E+03	-7.76	0.64	9	---
2200	22.4	4.7	0.7	0.3	646	385	1.79E+07	3.05E+06	4.53E+05	1.40E+05	2.00E+03	9.38E+02	-12.30	0.13	15	0.45
2300	25.8	4.0	0.5	0.3	729	386	1.36E+07	2.60E+06	9.75E+05	4.11E+05	5.10E+03	2.42E+03	-13.25	-0.16	1	---
0000	26.7	3.0	0.3	0.4	958	388	1.56E+07	3.28E+06	1.15E+06	4.98E+05	6.73E+03	3.27E+03	-14.94	-0.38	5	0.40
0100	29.9	2.3	0.5	0.4	1047	383	1.32E+07	2.35E+06	1.02E+06	4.21E+05	3.98E+03	1.93E+03	-15.02	-0.46	2	---
0200	28.7	2.0	0.5	0.5	1019	377	9.79E+06	1.38E+06	5.09E+05	1.86E+05	2.09E+03	9.81E+02	-11.79	-0.46	0	---
0300	26.6	2.1	0.5	0.4	1132	372	1.19E+07	4.41E+06	2.32E+06	1.12E+06	2.28E+04	1.09E+04	-12.03	-0.35	1	0.47
0400	26.6	2.3	0.5	0.4	1189	367	1.11E+07	2.54E+06	8.62E+05	3.05E+05	3.52E+03	1.79E+03	-10.93	-0.28	4	---
0500	25.0	2.4	0.5	0.3	1018	363	2.14E+07	5.23E+06	7.84E+05	2.26E+05	2.70E+03	1.36E+03	-12.00	-0.28	16	0.37
0600	28.6	2.2	0.5	0.4	971	364	2.91E+07	9.88E+06	5.38E+06	3.01E+06	3.35E+04	1.52E+04	-15.81	-0.35	7	---
0700	27.7	3.7	0.6	0.3	1093	361	2.21E+07	1.24E+07	7.59E+06	3.63E+06	2.57E+04	1.15E+04	-12.14	0.13	0	---
0800	26.1	5.7	0.7	0.3	813	356	1.10E+07	2.70E+06	1.01E+06	2.43E+05	6.05E+02	2.55E+02	-7.77	0.23	0	---
0900	24.7	7.3	0.8	0.3	660	356	6.50E+06	9.05E+05	2.41E+05	4.54E+04	3.63E+02	1.50E+02	-5.17	0.38	---	---

FUEL CONSUMPTION

EVENT	TIME	LOAD (kg)
Start of fire	2114	1.56
First Loading	2119	3.46
Second Loading	2148	1.96
Third Loading	2343	4.13
Fourth Loading	0102	0.65
Fifth Loading	0300	1.84
Sixth Loading	0427	2.94
Seventh Loading	0450	1.83

SAMPLING TIMES	
Start of long samples	2054-2104
Start of short samples	2159-0005
End of long and short samples	0613-0630

PM10 RESULTS ($\mu g/m^3$)

SAMPLE	CONCENTRATION	UNCERTAINTY
In-long	56	13
In-short	84	22
Out-long	9	4
Out-short	7	5

Summary of Results of Stove Test C.2

HOURLY AVERAGE DATA

Hour	Tin (°C)	Tout (°C)	Wind Speed (m/s)	In - Out CO (ppm)	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	Particle Count Concentration Number of Particles/m^3 .3-.5	.5-.7	.7-1.0	1-5	5-10	>10	Pressure Flue (Pa)	Pressure Wall (Pa)	Total PAH EcoChem (ng/m^3)	ACH (h^{-1})
1800	---	---	---	0.1	528	388	4.01E+06	9.40E+05	4.78E+05	2.22E+05	5.41E+03	2.64E+03	1.23	-0.21	---	---
1900	---	---	---	0.0	602	389	4.68E+06	1.20E+06	5.35E+05	2.16E+05	4.37E+03	2.11E+03	1.60	-0.16	0	---
2000	20.1	4.9	0.3	-0.4	692	409	7.39E+06	2.31E+06	1.09E+06	4.86E+05	1.28E+04	6.11E+03	-2.83	0.37	45	---
2100	21.2	4.2	0.3	-0.5	782	439	1.30E+07	3.51E+06	1.37E+06	5.47E+05	1.29E+04	6.24E+03	-7.31	-0.17	107	0.42
2200	23.2	3.1	0.3	-0.2	716	466	9.01E+06	1.10E+06	2.28E+05	6.15E+04	8.43E+02	3.76E+02	-12.64	-0.36	86	---
2300	24.6	2.6	0.3	0.1	788	462	1.02E+07	3.48E+06	1.90E+06	9.67E+05	2.81E+04	1.33E+04	-10.81	-0.45	100	0.33
0000	24.8	2.0	0.3	0.2	1005	446	1.01E+07	3.02E+06	1.32E+06	4.91E+05	6.44E+03	3.15E+03	-10.47	-0.54	97	---
0100	24.2	1.6	0.3	0.3	1084	439	1.00E+07	3.48E+06	1.76E+06	7.87E+05	1.16E+04	5.70E+03	-7.85	-0.62	87	---
0200	22.5	1.4	0.3	0.6	1024	447	8.22E+06	1.63E+06	6.14E+05	2.37E+05	5.06E+03	2.29E+03	-6.72	-0.57	65	0.42
0300	23.0	1.4	0.4	0.6	1006	449	1.21E+07	4.13E+06	2.01E+06	9.41E+05	2.28E+04	1.04E+04	-9.05	-0.57	74	---
0400	24.2	2.0	0.3	0.6	1073	441	1.80E+07	1.01E+07	6.73E+06	3.85E+06	7.63E+04	3.42E+04	-10.61	-0.53	90	0.48
0500	26.3	3.5	0.5	0.7	1293	410	1.90E+07	1.25E+07	7.33E+06	3.12E+06	1.49E+04	7.19E+03	-11.23	-0.60	43	---
0600	26.4	3.9	0.4	2.3	1114	406	1.53E+07	2.25E+07	9.99E+06	1.72E+06	5.48E+03	2.71E+03	-11.51	-0.30	6593	---
0700	---	---	---	1.5	905	419	3.57E+07	1.19E+07	1.73E+06	1.27E+05	7.20E+02	2.98E+02	---	---	1633	---
0800	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

FUEL CONSUMPTION

EVENT	TIME	LOAD (kg)
Start of fire	2028	1.56
First Loading	2033	1.99
Second Loading	2119	1.21
Third Loading	2130	1.00
Fourth Loading	2314	3.53
Fifth Loading	0108	2.52
Sixth Loading	0244	1.50
Seventh Loading	0407	3.27

SAMPLING TIMES	
Start of long samples	2018-2035
Start of short samples	2123-2137
End of long and short samples	0530-0552

PM10 RESULTS ($\mu g/m^3$)

SAMPLE	CONCENTRATION	UNCERTAINTY
In-long	81	19
In-short		
Out-long	32	8
Out-short		

Summary of Results of Stove Test C.3

HOURLY AVERAGE DATA

Hour	Tin (°C)	Tout (°C)	Wind Speed (m/s)	In - Out CO (ppm)	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	Particle Count Concentration Number of Particles/m^3 .3-.5	.5-.7	.7-1.0	1-5	5-10	>10	Pressure Flue (Pa)	Pressure Wall (Pa)	Total PAH EcoChem (ng/m^3)	ACH (h^{-1})
1900	19.7	7.6	0.6	0.0	489	386	5.57E+06	3.53E+05	6.31E+04	1.14E+04	8.43E+01	3.32E+01	0.08	0.00	---	---
2000	19.3	7.2	0.4	-0.1	482	395	5.50E+06	3.47E+05	8.50E+04	3.35E+04	1.24E+03	5.95E+02	0.46	0.04	1	---
2100	20.7	7.0	0.3	0.0	608	408	7.98E+06	1.30E+06	6.43E+05	3.13E+05	7.17E+03	3.39E+03	-5.48	0.29	16	---
2200	25.8	6.8	0.3	-0.1	653	410	8.53E+06	1.04E+06	4.13E+05	1.78E+05	2.41E+03	1.15E+03	-13.24	-0.03	13	0.47
2300	25.9	6.2	0.4	0.1	831	415	1.02E+07	2.74E+06	1.54E+06	7.83E+05	1.52E+04	7.28E+03	-11.64	-0.06	18	---
0000	26.3	5.8	0.4	0.4	993	398	1.27E+07	4.47E+06	2.28E+06	9.51E+05	8.94E+03	4.19E+03	-10.85	-0.14	7	---
0100	28.8	5.7	0.4	0.3	1023	389	1.28E+07	1.85E+06	5.56E+05	1.63E+05	1.10E+03	5.42E+02	-14.31	-0.30	4	0.43
0200	29.8	5.5	0.4	0.4	951	386	1.15E+07	1.16E+06	3.13E+05	1.00E+05	1.16E+03	5.83E+02	-12.48	-0.41	0	---
0300	27.9	5.2	0.6	0.5	927	376	1.52E+07	2.73E+06	4.59E+05	1.25E+05	1.62E+03	7.54E+02	-9.43	-0.30	0	0.48
0400	26.0	4.2	0.5	0.4	961	376	2.26E+07	5.26E+06	1.22E+06	4.64E+03	6.97E+03	3.35E+03	-9.18	-0.18	30	---
0500	25.3	3.6	0.6	0.4	1084	374	1.91E+07	3.28E+06	6.77E+05	2.28E+05	2.39E+03	1.15E+03	-9.70	-0.19	27	0.61
0600	26.3	3.7	0.6	0.2	1052	373	1.55E+07	2.15E+06	5.46E+05	2.21E+05	3.02E+03	1.49E+03	-14.19	0.12	26	---
0700	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
0800	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

FUEL CONSUMPTION

EVENT	TIME	LOAD (kg)
Start of fire	2126	2.07
First Loading	2130	1.27
Second Loading	2310	3.10
Third Loading	0045	3.63
Fourth Loading	0318	3.13
Fifth Loading	0537	1.61

SAMPLING TIMES	
Start of long samples	2100-2118
Start of short samples	2256-2332
End of long and short samples	0631-0647

PM10 RESULTS ($\mu g/m^3$)

SAMPLE	CONCENTRATION	UNCERTAINTY
In-long	20	6
In-short	15	6
Out-long	25	7
Out-short	25	7

Summary of Results of Stove Test D.1

HOURLY AVERAGE DATA

Hour	Tin (°C)	Tout (°C)	Wind Speed (m/s)	In - Out CO (ppm)	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	Particle Count Concentration Number of Particles/m^3 .3-.5	.5-.7	.7-1.0	1-5	5-10	>10	Pressure Flue (Pa)	Pressure Wall (Pa)	Total PAH EcoChem (ng/m^3)	ACH (h^{-1})
1900	21.7	7.7	0.7	0.0	402	404	---	---	---	---	---	---	-0.05	-0.04	---	---
2000	19.9	6.6	0.7	0.1	410	411	---	---	---	---	---	---	0.00	0.01	0	---
2100	19.0	5.6	0.6	0.0	618	410	---	---	---	---	---	---	0.05	0.04	2	---
2200	22.5	5.3	0.8	0.3	787	384	---	---	---	---	---	---	-0.03	0.11	302	0.49
2300	31.4	4.5	0.7	0.6	840	381	8.42E+06	1.74E+06	8.23E+05	6.05E+05	3.01E+03	2.53E+03	-10.95	-0.69	47	---
0000	31.3	4.0	0.8	1.0	1020	375	7.12E+06	4.43E+06	3.15E+06	2.74E+06	1.26E+04	9.93E+03	-14.90	-1.01	74	0.42
0100	31.3	3.2	0.7	1.1	1150	372	1.63E+07	8.31E+06	3.14E+06	1.17E+06	3.94E+03	3.19E+03	-13.81	-1.19	1938	---
0200	30.3	2.7	0.7	1.1	1071	366	1.49E+07	2.85E+06	8.16E+05	3.81E+05	1.90E+03	1.51E+03	-13.16	-1.21	715	---
0300	30.2	1.7	0.7	1.2	1011	361	1.05E+07	2.43E+06	1.26E+06	9.90E+05	4.83E+03	4.01E+03	-13.66	-1.17	198	0.51
0400	30.3	1.2	0.6	1.0	1089	359	8.25E+06	2.35E+06	1.29E+06	1.02E+06	6.37E+03	5.71E+03	-14.65	-1.34	36	---
0500	31.6	0.3	0.3	1.1	1301	360	5.63E+06	4.74E+06	3.79E+06	3.66E+06	1.66E+04	1.30E+04	-16.66	-1.34	96	---
0600	32.2	-0.4	0.3	1.0	1037	358	4.16E+06	1.45E+06	5.69E+05	2.05E+05	7.46E+02	5.24E+02	-13.78	-1.65	11	---
0700	29.9	0.1	0.3	0.6	848	366	3.25E+06	9.11E+05	4.16E+05	3.34E+05	2.81E+03	2.40E+03	-13.04	-1.37	17	0.48
0800	31.3	2.5	0.4	0.7	707	354	3.24E+06	6.29E+05	2.12E+05	1.15E+05	6.68E+02	4.59E+02	-16.87	-0.82	27	---
0900	31.9	5.2	0.6	0.6	576	350	3.02E+06	4.20E+05	8.68E+04	5.09E+04	4.68E+02	3.74E+02	-12.91	-0.75	1	---
1000	30.7	6.9	0.6	0.4	505	351	3.39E+06	4.32E+05	6.95E+04	2.81E+04	2.12E+02	1.31E+02	-9.49	-0.81	---	---

FUEL CONSUMPTION

EVENT	TIME	LOAD (kg)
Start of fire	2154	2.22
First Loading	2201	2.52
Second Loading	2232	3.11
Third Loading	0003	2.99
Fourth Loading	0114	2.66
Fifth Loading	0237	2.43
Sixth Loading	0528	4.65

SAMPLING TIMES	
Start of long samples	2139-2150
Start of short samples	2300-2315
End of long and short samples	0734-0744

PM10 RESULTS ($\mu g/m^3$)

SAMPLE	CONCENTRATION	UNCERTAINTY
In-long	69	16
In-short	58	14
Out-long	7	4
Out-short	8	4

Summary of Results of Stove Test D.2

HOURLY AVERAGE DATA

Hour	Tin (°C)	Tout (°C)	Wind Speed (m/s)	In - Out CO (ppm)	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	Particle Count Concentration Number of Particles/m^3 .3-.5	.5-.7	.7-1.0	1-5	5-10	>10	Pressure Flue (Pa)	Pressure Wall (Pa)	Total PAH EcoChem (ng/m^3)	ACH (h^{-1})
1800	29.1	15.2	0.6	0.2	400	366	2.48E+06	2.91E+05	4.07E+04	9.18E+03	8.10E+01	2.81E+01	-0.75	-0.41	---	---
1900	27.3	10.5	0.3	0.1	403	372	2.35E+06	2.58E+05	3.33E+04	7.18E+03	3.99E+01	1.37E+01	-0.34	-0.32	0	---
2000	25.2	9.5	0.4	-0.2	481	396	3.61E+06	7.02E+05	2.89E+05	2.56E+05	2.65E+03	2.12E+03	1.08	0.73	13	---
2100	27.2	8.4	1.1	0.1	629	389	7.32E+06	1.37E+06	4.65E+05	3.42E+05	2.41E+03	2.12E+03	-14.59	-0.01	220	---
2200	33.0	7.0	0.9	0.3	689	393	5.95E+06	1.14E+06	4.88E+05	3.94E+05	2.69E+03	2.31E+03	-10.32	-0.70	69	---
2300	32.6	6.4	1.0	0.5	905	392	5.75E+06	2.84E+06	1.86E+06	1.48E+06	6.04E+03	5.01E+03	-11.10	-0.83	43	0.40
0000	33.3	5.9	0.8	0.7	1005	386	6.12E+06	1.75E+06	7.71E+05	4.52E+05	2.43E+03	1.89E+03	-11.64	-0.83	103	---
0100	32.9	5.3	0.6	0.6	978	377	8.23E+06	1.97E+06	3.93E+05	1.87E+05	8.51E+02	6.95E+02	-11.84	-0.73	32	0.59
0200	33.5	4.6	0.4	0.6	918	375	6.40E+06	1.19E+06	3.32E+05	2.32E+05	1.36E+03	1.09E+03	-12.67	-0.59	39	---
0300	33.5	4.1	0.6	0.8	879	371	6.04E+06	3.97E+06	2.68E+06	2.11E+06	7.13E+03	5.71E+03	-12.72	-0.70	211	---
0400	32.8	3.7	0.6	1.6	931	368	7.19E+06	2.33E+06	1.05E+06	4.94E+06	1.70E+03	1.25E+03	-13.48	-0.43	1472	0.68
0500	33.2	3.3	0.9	1.0	997	367	5.47E+06	1.16E+06	4.36E+05	2.47E+05	1.36E+03	1.10E+03	-14.10	-0.71	122	---
0600	---	---	---	---	---	---	---	---	---	---	---	---	---	---	29	---
0700	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
0800	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

FUEL CONSUMPTION

EVENT	TIME	LOAD (kg)
Start of fire	2105	2.49
First Loading	2109	1.46
Second Loading	2139	2.37
Third Loading	2257	1.76
Fourth Loading	0002	3.95
Fifth Loading	0213	1.44
Sixth Loading	0313	1.41
Seventh Loading	0404	1.34
Eighth Loading	0520	1.67

SAMPLING TIMES	
Start of long samples	2049-2100
Start of short samples	2150-2200
End of long and short samples	0600-0617

PM10 RESULTS ($\mu g/m^3$)

SAMPLE	CONCENTRATION	UNCERTAINTY
In-long	27	7
In-short	15	6
Out-long	8	4
Out-short	34	9

Summary of Results of Stove Test D.3

HOURLY AVERAGE DATA

Hour	Tin (°C)	Tout (°C)	Wind Speed (m/s)	In - Out CO (ppm)	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	Particle Count Concentration Number of Particles/m^3 .3-.5	.5-.7	.7-1.0	1-5	5-10	>10	Pressure Flue (Pa)	Pressure Wall (Pa)	Total PAH EcoChem (ng/m^3)	ACH (h^{-1})
1800	27.2	21.2	0.7	0.0	392	382	3.40E+06	7.13E+05	2.89E+05	1.34E+05	3.49E+03	1.61E+03	-0.54	-0.05	---	---
1900	24.0	15.7	0.4	0.0	376	376	5.03E+06	7.51E+05	1.99E+05	6.10E+04	5.55E+02	2.52E+02	0.11	-0.01	0	---
2000	22.1	14.0	0.3	0.0	407	388	5.65E+06	9.84E+05	3.21E+05	1.26E+05	3.00E+03	1.37E+03	0.43	0.06	0	---
2100	24.1	12.5	0.3	0.1	599	388	8.57E+06	1.61E+06	6.16E+05	2.79E+05	5.81E+03	2.81E+03	-8.32	0.24	413	---
2200	32.4	11.6	0.3	0.5	782	385	7.76E+06	1.82E+06	8.08E+05	3.42E+05	4.20E+03	2.05E+03	-10.00	-0.51	163	0.33
2300	33.0	10.4	0.3	0.8	891	390	9.64E+06	3.28E+06	1.34E+06	5.44E+05	5.84E+03	2.72E+03	-10.01	-0.44	130	---
0000	34.9	10.0	0.3	0.9	879	395	7.99E+06	1.96E+06	6.63E+05	2.52E+05	4.39E+03	2.02E+03	-11.25	-0.70	60	0.32
0100	34.1	9.8	0.3	0.8	783	383	5.89E+06	2.02E+06	9.87E+05	4.81E+05	4.80E+03	2.15E+03	-9.05	-0.82	0	---
0200	34.0	9.4	0.3	---	1022	382	1.29E+07	8.52E+06	5.13E+06	2.52E+06	1.70E+04	7.23E+03	-9.27	-0.81	0	---
0300	35.8	9.2	0.3	---	1164	376	1.52E+07	6.61E+06	3.03E+06	1.15E+06	4.64E+03	1.97E+03	-11.58	-0.78	205	0.41
0400	35.8	8.6	0.4	---	---	---	9.80E+06	4.32E+06	2.05E+06	8.38E+05	7.08E+03	3.11E+03	-9.32	-0.88	6	---
0500	35.2	8.1	0.3	---	---	---	1.22E+07	7.26E+06	4.37E+06	2.24E+06	1.02E+04	3.81E+03	-11.62	-0.70	80	0.46
0600	35.1	7.6	0.3	---	---	---	8.89E+06	3.54E+06	1.70E+06	6.46E+05	2.06E+03	8.46E+02	-11.68	-0.82	12	---
0700	34.2	7.4	0.3	---	---	---	6.73E+06	2.44E+06	1.15E+06	4.75E+05	2.37E+03	9.91E+02	-12.46	-0.56	2	---
0800	32.7	8.0	0.3	---	---	---	4.58E+06	1.23E+06	5.03E+05	2.01E+05	6.79E+02	2.37E+02	-10.09	-0.33	3	0.54
0900	30.7	10.5	0.5	---	---	---	3.75E+06	6.41E+05	1.66E+05	4.62E+04	2.10E+02	8.73E+01	-6.22	-0.13	---	---
1000	30.0	12.2	0.6	---	---	---	3.13E+06	4.45E+05	9.05E+04	2.52E+04	1.52E+02	5.95E+01	-3.70	-0.20	---	0.35

FUEL CONSUMPTION

EVENT	TIME	LOAD (kg)
Start of fire	2117	1.91
First Loading	2121	1.89
Second Loading	2137	3.82
Third Loading	2337	4.10
Fourth Loading	0255	2.07
Fifth Loading	0510	3.87

SAMPLING TIMES	
Start of long samples	2056-2109
Start of short samples	2159-2217
End of long and short samples	0702-0714

PM10 RESULTS ($\mu g/m^3$)

SAMPLE	CONCENTRATION	UNCERTAINTY
In-long	30	7
In-short	57	14
Out-long	10	4
Out-short	7	4

Summary of Results of Stove Test E.1

HOURLY AVERAGE DATA

Hour	Tin (°C)	Tout (°C)	Wind Speed (m/s)	In - Out CO (ppm)	Indoor CO_2 (ppm)	Outdoor CO_2 (ppm)	Particle Count Concentration Number of Particles/m^3 .3-.5	.5-.7	.7-1.0	1-5	5-10	>10	Pressure Flue (Pa)	Pressure Wall (Pa)	Total PAH EcoChem (ng/m^3)	ACH (h^{-1})
1800	25.2	13.1	0.5	0.1	850	272	7.60E+06	2.90E+06	1.39E+06	7.76E+05	1.21E+03	9.03E+02	-0.24	0.06	---	---
1900	24.6	11.9	0.4	0.1	699	272	7.96E+06	1.74E+06	3.37E+05	6.02E+04	1.58E+02	1.11E+02	0.06	0.03	---	0.28
2000	24.2	10.9	0.3	0.1	598	276	6.12E+06	9.37E+05	1.29E+05	3.32E+04	1.12E+02	8.52E+01	0.39	-0.16	---	---
2100	24.6	10.5	0.3	0.0	526	275	5.89E+06	8.23E+05	1.15E+05	3.65E+04	1.91E+02	1.13E+02	0.13	-0.03	---	0.31
2200	24.2	9.9	0.4	0.1	468	274	5.63E+06	6.08E+05	7.34E+04	3.10E+04	1.67E+02	1.00E+02	-0.29	0.03	---	---
2300	24.2	9.2	0.4	0.1	427	278	5.63E+06	5.37E+05	5.91E+04	2.44E+04	9.53E+01	4.52E+01	-0.33	-0.02	---	---
0000	24.2	9.0	0.3	0.0	398	282	5.34E+06	5.17E+05	5.72E+04	2.34E+04	6.74E+01	4.16E+01	0.07	-0.15	---	0.24
0100	24.3	9.0	0.3	0.1	377	282	5.00E+06	4.73E+05	5.31E+04	2.39E+04	8.78E+01	5.20E+01	0.04	-0.11	---	---
0200	24.5	8.9	0.3	0.0	362	283	4.75E+06	4.56E+05	5.37E+04	2.39E+04	5.59E+01	3.73E+01	0.01	-0.11	---	0.29
0300	24.4	8.8	0.3	0.1	351	285	4.06E+06	4.04E+05	5.14E+04	2.17E+04	3.79E+01	2.72E+01	-0.02	-0.14	---	---
0400	24.5	8.7	0.3	0.1	343	287	3.81E+06	4.19E+05	5.47E+04	2.29E+04	7.09E+01	4.23E+01	0.12	-0.18	---	---
0500	24.4	8.6	0.3	0.0	337	289	3.89E+06	4.85E+05	6.44E+04	2.30E+04	7.04E+01	5.60E+01	0.11	-0.18	---	0.23
0600	24.2	8.3	0.3	0.0	333	289	3.99E+06	5.18E+05	6.58E+04	2.13E+04	3.59E+01	3.73E+01	-0.13	-0.16	---	---
0700	24.0	8.0	0.2	0.0	394	290	4.52E+06	1.08E+06	4.50E+05	3.70E+05	2.27E+03	1.96E+03	-0.01	-0.18	---	0.28
0800	24.4	9.1	0.3	-0.1	380	286	4.33E+06	7.21E+05	1.36E+05	3.98E+04	6.94E+01	4.80E+01	0.00	-0.07	---	---
0900	24.3	10.3	0.3	0.1	367	283	3.88E+06	5.60E+05	7.94E+04	2.70E+04	1.33E+02	6.60E+01	0.10	0.00	---	0.20
1000	24.6	12.3	0.4	0.0	379	281	3.74E+06	6.17E+05	1.71E+05	1.29E+05	1.06E+03	9.47E+02	0.31	0.09	---	---
1100	25.1	13.8	0.4	0.0	362	281	3.43E+06	4.56E+05	7.62E+04	2.40E+04	8.30E+01	4.43E+01	0.23	0.11	---	0.20
1200	26.3	14.6	0.4	0.0	349	280	3.71E+06	4.58E+05	7.26E+04	2.52E+04	7.64E+01	3.36E+01	0.13	-0.01	---	---
1300	27.2	14.7	0.4	0.0	338	281	3.90E+06	4.38E+05	6.73E+04	2.26E+04	4.14E+01	3.28E+01	-0.05	-0.06	---	---
1400	27.6	14.9	0.4	0.0	331	279	4.08E+06	4.42E+05	7.00E+04	2.52E+04	3.22E+01	4.15E+01	-0.16	-0.06	---	---
1500	27.8	14.1	0.4	0.1	385	283	4.52E+06	6.17E+05	2.59E+05	2.77E+05	2.74E+03	2.37E+03	-0.38	-0.13	---	0.25
1600	27.4	12.6	0.3	0.0	619	281	5.83E+06	3.21E+06	2.15E+06	1.60E+06	3.29E+03	2.33E+03	0.07	-0.05	---	---

FUEL CONSUMPTION

EVENT	TIME	LOAD (kg)
Start of fire	N/A	NO FIRE

SAMPLING TIMES	
Start of long samples	0707-0719
Start of short samples	0954-1000
End of long and short samples	1701-1723

PM10 RESULTS ($\mu g/m^3$)

SAMPLE	CONCENTRATION	UNCERTAINTY
In-long	10	4
In-short	12	5
Out-long	11	4
Out-short	12	5

APPENDIX D PAH CONCENTRATION RESULTS

This appendix contains all of the PAH concentration measurement results from the sorbent tubes. The data in this table were obtained based on the analysis of these tubes performed by the Chemical Science and Technology Laboratory at NIST and contained in their Report of Analysis No. 835-94-092. The compound names corresponding to the concentration measurements have been abbreviated at the top of the columns. From left to right, the abbreviations and PAHs represented are: NAPHTH is naphthalene, PHEN is phenanthrene, ANTH is anthracene, FLUOR is fluoranthene, PYRENE is pyrene, B[a]A is benz[a]anthracene, CHRYS is chrysene, PERY is perylene, B[k]F is benzo[k]fluoranthene, B[a]P is benzo[a]pyrene, DB[a,h]A is dibenz[a,h]anthracene, B[ghi]P is benzo[ghi]perylene, and INDENO is indeno[1,2,3-cd]pyrene. Tests A.2 and A.3 contain the results of breakthrough tests conducted at sample airflow rates of 20 and 15 L/min respectively. The designations D and U correspond to the downstream and upstream sorbent tubes that were configured in series for these tests. If there was no breakthrough, the D tube would have collected no compounds. The designation S corresponds to the single sample duplicate of the upstream long and short test samples. The entries denoted with the symbol * correspond to negative concentration values after the mass on the blank sorbent tube was subtracted. Values of 0.0 correspond to concentrations below the detection limit; no entry corresponds to cases when the compound was not detected. As seen in the table, for compounds of interest (benz[a]anthracene to indeno[1,2,3-cd]pyrene), there was negligible breakthrough to the downstream tubes. All other tests, except A.4, were conducted at a lower sample airflow rate of 10 L/min, which would lead to even less breakthrough. For tests A.4 and D.1, the average of all other blank values were used because the sample blanks for these tests were not valid.

Sample	NAPHTH (ng/m^3)	PHEN (ng/m^3)	ANTH (ng/m^3)	FLUOR (ng/m^3)	PYRENE (ng/m^3)	B[a]A (ng/m^3)	CHRYS (ng/m^3)	PERY (ng/m^3)	B[k]F (ng/m^3)	B[a]P (ng/m^3)	DB[ah]A (ng/m^3)	B[ghi]P (ng/m^3)	INDENO (ng/m^3)
Test A.1													
In-Long	777.6	48.4	0.6	5.5	4.2	*	*	0.7	0.9	0.7		2.4	
In-Long	684.7	50.1	1.3	5.2	4.5	*	0.4	0.5	0.3	0.5	0.1	0.8	0.5
In-Short	900.8	53.7	0.7	4.9	4.0	*	1.4	1.0	0.3	0.5	*	0.9	1.1
In-Short	879.6	53.0	1.1	5.9	4.3	*	0.3	1.0	0.3	0.4	*	1.5	
Out-Long	301.0	18.9	0.7	7.7	4.3	*	*	0.4	0.4	0.2			
Test A.2													
In-Long-D	*	3.2	*	0.5	0.3	*	*	*	0.1	0.0			
In-Long-U	585.2	58.7	0.8	3.0	5.7	0.5	1.8	0.1	0.5	0.8	0.5	0.8	0.5
In-Long-S	632.9	68.2	0.9	4.1	5.3	0.9	2.6	0.1	0.5	0.8	0.6	0.9	0.6
In-Short-D	*	4.1	*	0.8	0.6	*	*	*	0.1				
In-Short-U	659.0	67.6	0.8	4.0	5.5	*	0.3	*	0.2	0.2	0.3	0.4	0.4
In-Short-S		56.7	1.1	4.2	5.1	0.3	1.5	*	0.1	0.2	0.4	0.2	0.3
Out-Long	98.7	6.9	0.0	1.8	1.9	*	0.3	0.1	0.3	0.5	0.1	0.4	0.6
Out-Short	148.0	8.5	0.0	6.9	2.3	0.0	0.7	0.1	0.5	0.7	0.2	0.4	0.5
Test A.3													
In-Long-U	580.9	42.6	1.6	3.9	4.2	*	0.5	0.0	0.3	0.6	0.3	0.6	0.8
In-Long-D	5.5	2.8	0.1	0.5	0.7	*	*	*	0.1	0.1	0.0	0.2	0.2
In-Long-S	599.4	43.0	1.5	4.0	4.6	*	1.0	0.1	0.4	0.7	0.1	0.5	0.9
In-Short-U	622.5	47.3	1.5	3.7	4.8	*	0.6	0.0	0.2	0.5	0.1	0.7	0.9
In-Short-D	*	3.4	0.1	0.6	0.5	*	*	*	0.0	0.1			
In-Short-S	669.1	49.4	1.8	4.0	4.6	*	0.8	0.0	0.3	0.6	0.1	0.7	0.9
Out-Long	52.9	0.1	0.5	1.0	1.0	0.5	0.4	0.0	0.2	0.2	0.0	0.1	0.2
Out-Short	52.2	*	0.7	1.2	0.8	0.0	0.4	*	0.1	0.1	*	0.3	0.2
Test A.4													
In-Long	453.7	24.0	0.9	2.0	2.2	*	0.1	0.1	0.1	0.2	0.1	0.3	0.3
In-Long	466.3	26.1	1.0	1.6	1.8	*	0.1	0.0	0.1	0.2	0.0	0.2	0.2
In-Short	495.3	27.5	1.0	1.9	1.9	0.1	*	0.0	0.1	0.2	*	0.3	0.2
In-Short	505.9	24.4	0.9	2.5	2.4	0.0	0.4	0.0	0.1	0.2	0.0	0.2	0.3
Out-Long	162.9	11.8	0.9	3.9	3.2	*	0.1	0.1	0.2	0.2	0.1	0.7	0.3
Out-Short	140.7	8.0	0.5	2.3	2.1	*	*	0.1	0.1	0.1	*	0.2	0.2

Sample	NAPHTH (ng/m^3)	PHEN (ng/m^3)	ANTH (ng/m^3)	FLUOR (ng/m^3)	PYRENE (ng/m^3)	B[a]A (ng/m^3)	CHRYS (ng/m^3)	PERY (ng/m^3)	B[k]F (ng/m^3)	B[a]P (ng/m^3)	DB[ah]A (ng/m^3)	B[ghi]P (ng/m^3)	INDENO (ng/m^3)
Test B.2													
In-Long	439.4	30.6	1.1	4.4	5.3	0.3	1.9	0.3	0.6	1.5	0.5	1.4	1.8
In-Long	430.3	30.1	1.1	2.8	4.8	0.3	1.9	0.3	0.6	1.4	0.5	1.2	1.2
In-Short	420.8	32.1	0.8	3.8	3.8	0.3	1.6	0.1	0.2	0.5	0.1	0.6	0.7
In-Short	416.4	31.0	0.7	3.4	3.3	0.1	1.4	0.1	0.2	0.3	0.2	0.5	0.4
Out-Long	51.0	1.9	*	1.1	0.3	0.0	0.2	0.1	0.1	0.2	0.0	0.2	0.2
Out-Short	39.2	1.2	0.0	1.2	0.2	*	0.2	0.1	0.1	0.1			
Test B.3													
In-Long	417.5	34.5	1.4	3.2	3.4	0.4	1.5	0.0	0.1	0.2	0.1	0.2	0.5
In-Long	426.2	34.6	1.5	3.2	3.6	0.3	1.4	0.1	0.1	0.2	0.1	0.4	0.4
In-Short	474.8	40.7	1.6	4.9	3.9	0.2	1.2	0.0	0.1	0.1	0.1	0.3	0.2
In-Short	478.6	40.5	1.6	3.9	4.3	0.2	0.8	*	0.1	0.1	0.1	0.5	0.2
Out-Long	304.5	10.8	1.2	3.6	3.3	0.3	1.1	0.1	0.4	0.6	0.3	0.6	0.3
Out-Short	236.2	8.3	0.7	2.3	2.0	0.4	0.7	0.1	0.3	0.4	0.1	0.4	0.3
Test B.4													
In-Long	586.4	37.8	1.7	1.5	2.8	*	1.4	*	0.1	0.2	0.1	0.2	0.1
In-Long	571.3	37.3	1.7	2.5	2.9	*	0.3	0.1	0.1	0.1	0.0	0.1	0.2
In-Short	641.5	39.4	1.4	2.4	3.5	*	0.4	*	0.1	0.1	0.1	0.1	
In-Short	552.6	39.2	1.6	3.8	3.0	*	0.1	0.0	0.1	0.1	0.1	0.1	
Out-Long	482.6	16.4	0.9	3.3	2.3	*	*	0.1	0.3	0.4	0.1	0.6	0.3
Out-Short	459.9	15.8	0.4	2.2	2.1	*	0.1	0.1	0.3	0.4	0.1	0.8	0.5

Sample	NAPHTH (ng/m^3)	PHEN (ng/m^3)	ANTH (ng/m^3)	FLUOR (ng/m^3)	PYRENE (ng/m^3)	B[a]A (ng/m^3)	CHRYS (ng/m^3)	PERY (ng/m^3)	B[k]F (ng/m^3)	B[a]P (ng/m^3)	DB[ah]A (ng/m^3)	B[ghi]P (ng/m^3)	INDENO (ng/m^3)
Test C.1													
In-Long	360.2	36.0	1.4	0.8	2.6	0.5	0.7	0.0	0.1	0.2	*	0.3	0.7
In-Long	357.9	35.9	1.0	2.3	3.5	0.3	0.7	0.0	0.1	0.1	*	0.3	0.1
In-Short	369.2	37.6	1.5	5.0	3.0	0.4	1.4	0.2	0.1	0.1	*	0.1	0.2
In-Short	363.6	37.1	1.5	2.7	3.4	0.2	1.2	0.0	0.1	0.2			0.1
Out-Long	48.7	2.9	0.0	0.1	0.1	0.1	*	0.1	0.0	0.1	0.3		
Out-Short	58.3	2.8	0.1	1.5	0.2	0.2	*	0.1	0.0	0.1	0.6	0.4	0.3
Test C.2													
In-Long	522.7	28.8	0.6	1.2	2.1	0.1	0.9	0.1	0.1	0.2	0.7	0.3	
In-Long	454.2	29.3	0.6	0.1	2.4	0.2	1.4	0.1	0.1	0.2	0.8	0.5	0.2
In-Short	454.1	29.3	0.6	1.5	2.3	0.1	1.0	0.1	0.1	0.2	0.8	0.4	0.3
In-Short	996.3	30.9	0.6	1.9	2.3	*	0.8	0.1	0.3	0.2	0.1	0.2	
Out-Long	1041.7	30.7	2.2	5.6	5.6	0.1	1.7	0.3	0.7	1.3	0.4	1.3	
Out-Short	1085.9	30.3	2.2	1.1	5.3	0.1	1.9	0.4	0.7	1.4	0.3	1.4	1.3
Test C.3													
In-Long	512.0	41.4	1.0	2.2	3.4	*	1.0	0.1	0.1	0.1			
In-Long	503.1	41.0	*	3.2	3.6	*	1.0	0.1	0.1	0.1	0.0	0.1	
In-Short	522.6	43.7	0.9	2.2	3.2	*	0.2	0.2	0.1	0.1	0.1	0.2	
In-Short	512.3	43.1	0.9	3.5	3.4	*	1.1	0.1	0.1	0.1	0.1	0.1	
Out-Long	268.4	10.2	*	2.3	1.3	*	0.2	0.2	0.2	0.1		0.3	0.2
Out-Short	218.3	7.9	*	1.7	0.7	*	0.0	0.1	0.1	0.2			

Sample	NAPHTH (ng/m^3)	PHEN (ng/m^3)	ANTH (ng/m^3)	FLUOR (ng/m^3)	PYRENE (ng/m^3)	B[a]A (ng/m^3)	CHRYS (ng/m^3)	PERY (ng/m^3)	B[k]F (ng/m^3)	B[a]P (ng/m^3)	DB[ah]A (ng/m^3)	B[ghi]P (ng/m^3)	INDENO (ng/m^3)
Test D.1													
In-Long	391.7	50.0	1.5	3.3	4.8	0.1	2.1	0.1	0.1	0.3	0.2	0.3	0.5
In-Long	409.8	52.7	1.6	2.7	5.2	*	3.7	0.1	0.1	0.3	0.1	0.5	0.3
In-Short	423.2	54.3	1.6	4.1	5.0	*	1.6	0.0	0.1	0.2	0.1	0.3	0.3
In-Short	430.7	54.0	1.6	4.1	4.7	0.1	2.0	*	0.1	0.2	0.1	0.4	0.7
Out-Long	155.0	4.4	0.0	1.1	0.9	*	*	0.0	0.1	0.1	0.0	0.2	0.2
Out-Short	105.3	3.7	*	1.2	0.9	0.1	*	0.0	0.1	0.1			
Test D.2													
In-Long	446.3	59.8	1.7	*	6.5	1.1	2.3	0.1	0.1	0.2	1.0	0.4	0.4
In-Long	451.2	59.7	1.7	5.7	7.2	1.0	3.0	0.1	0.1	0.2	0.9	0.3	0.2
In-Short	462.5	60.9	1.5	4.4	6.4	0.9	2.7	0.1	0.1	0.2	1.0	0.2	
In-Short	448.5	60.2	1.2	3.8	6.6	0.9	2.4	0.1	0.1	0.1	0.8	0.3	0.5
Out-Long	282.4	12.5	8.0	2.9	1.4	*	0.6	0.1	0.2	0.2	0.7	0.4	
Out-Short	219.5	9.9	8.0	1.7	0.9	0.1	0.4	0.1	0.1	0.1	0.7	0.2	
Test D.3													
In-Long	630.0	68.3	1.8	4.1	7.8	1.1	3.7	*	0.2	0.4	0.1	0.4	0.6
In-Long	421.6	67.7	2.1	4.8	0.5	1.4	3.5	*	0.2	0.3	0.1	0.3	0.5
In-Short	436.2	71.2	1.9	4.9	7.9	0.7	2.8	*	0.1	0.1	0.1	0.3	0.3
In-Short	474.5	69.2	1.6	3.9	7.1	1.0	3.0	*	0.1	0.1	0.1	0.3	0.2
Out-Long	61.5	3.5	0.0	1.0	0.7	0.3	0.2	*	0.1	0.1			
Out-Short	71.9	4.2	0.0	1.2	0.8	1.1	0.4	*	0.1	0.1			
Test E.1													
In-Long	890.5	34.5	0.8	2.5	2.2	0.4	0.8	0.0	0.0	0.0			
In-Long	934.2	33.9	0.8	1.8	2.6	0.1	0.9	0.0					
In-Short	946.2	37.3	0.9	2.0	2.8	0.1	0.7	0.1	0.0	0.0			
Out-Long	111.2	6.3	0.1	1.2	0.5	0.3	0.1	0.0	0.0	0.0		0.2	0.3
Out-Short	95.7	6.1	0.1	1.2	0.5	0.4	0.1	0.1	0.0				